

IUCN Species Survival Commission

Polar Bears

Proceedings of the Twelfth Working Meeting
of the IUCN/SSC Polar Bear Specialist Group
3–7 February 1997, Oslo, Norway

Compiled and edited by
Andrew E. Derocher, Gerald W. Garner,
Nicholas J. Lunn and Øystein Wiig



Occasional Paper of the IUCN Species Survival Commission No. 19

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**IUCN – The World Conservation Union
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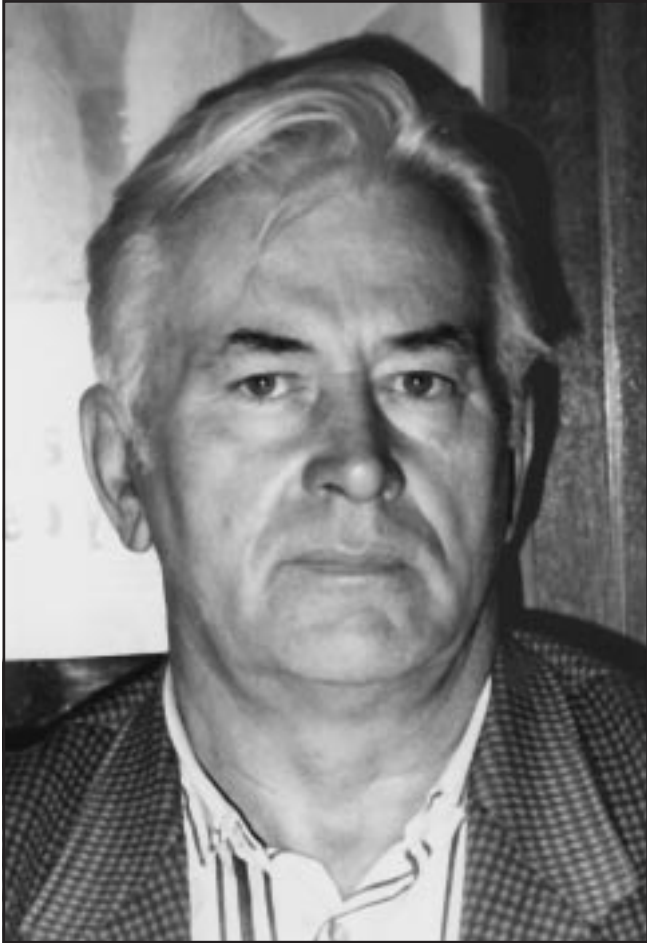
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The Department of the Environment, Transport and the Regions, UK, (DETR) supports a Red List Officer post at the SSC Centre in Cambridge, UK, where the SSC Trade Programme staff are also located. Together with two other Government-funded agencies, Scottish Natural Heritage and the Royal Botanic Gardens, Kew, the DETR is also financing a specialist plants officer. Further support for the centre is being offered by two NGO members of IUCN: the World Wide Fund for Nature – UK, and Conservation International, US.

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Dedication



Professor Savva M. Uspenski, the well-known Russian biologist and one of the original members of the IUCN/SSC Polar Bear Specialist Group, passed away on April 17, 1996. Professor Uspenski conducted much of the original research on polar bears in Russia. His first expedition, in 1964, was dedicated to the study of female polar bears in their maternity dens on Wrangel Island. Through his initiative, a research station of the All-Union Research Institute for Nature Protection and Nature Reserves (since 1991, re-named the All-Russian Research Institute for Nature Protection) was

established on Wrangel Island in 1969 for the purpose of studying polar bears. Investigations of the ecology and behaviour of polar bears in maternity dens during winter were carried out at this station and in other areas of the island by Professor Uspenski and his colleagues A. Kistchinski and S.E. Belikov until 1979, and later by other biologists from the State Nature Reserve.

During 1980–90, studies of the ecology of polar bears also included Herald Island and the northern coast of the Chukotka peninsula, a primary objective of which was to count the maternity dens in each area. Later, these investigations were carried out in other parts of the Russian Arctic as well. Although Professor Uspenski did not take part in the field work of these later expeditions, his support and advice were important to the success of the scientific programs.

Professor Uspenski was born December 9, 1920 in the town of Zvenigorod, near Moscow. After studying at the Moscow Fur-Down Institute in 1937, he tied his future to the Arctic. Besides conducting research on polar bears, he studied birds, was instrumental in the development of the natural protected areas network in the Russian Arctic, and was one of those responsible for introducing muskox in Russia. In 1963, he defended his Doctor of Philosophy in Zoology on avifauna of high latitudes. He remained a member of the Polar Bear Specialist Group until after the 10th Working Meeting of the Group, which was held for the first time in Russia, in autumn 1988.

Professor Uspenski published over 200 scientific papers, brochures and books. His books include *The Birds of the Soviet Arctic*, *Polar Bear*, and scientific-popular books such as *The Home of the Polar Bear*, *Living on the Ice*, and others. Some of his books have been translated into German and English. He was a long-standing editor of the magazine *Game* and active in scientific matters up to the time of his death. The memory of Professor Uspenski and his contributions to arctic biology will be remembered by his many colleagues and friends.

Foreword

Following the First International Scientific Meeting on the Polar Bear which was held in Fairbanks, Alaska in 1965, the Polar Bear Specialist Group was formed to co-ordinate research and management of polar bears. Eight years following the First Scientific Meeting, the International Agreement on the Conservation of Polar Bears was signed by the Governments of Canada, Denmark, Norway, the Union of Soviet Socialist Republics, and the United States. Article VII of the Agreement states that “The Contracting Parties shall conduct national research programmes on polar bears, particularly research relating to the conservation and management of the species. They shall as appropriate co-ordinate such research with research carried out by other Parties, consult with other Parties on the management of migrating polar bear populations, and exchange information on research and management programmes, research results and data on bears taken.”

As part of their commitment to fulfil the intent of the Agreement, representatives of all five signatory nations, together with invited specialists, attended the 12th Working Meeting of the IUCN/SSC Polar Bear Specialist Group that was held 3–7 February 1997 in Oslo, Norway and hosted by the Norwegian Polar Institute. During the intervening years since the previous meeting (Copenhagen, 1993), new insights into the ecology and management of polar bears have occurred. Research and management issues pertaining to polar bears are becoming increasingly more complex. Although other issues exist, two of the most important current concerns are: the impacts of toxic chemicals and the potential impacts of global climate change. Given the subtlety of the impacts of both threats, it is unlikely that definitive conclusions can be made in the near future. However,

extensive discussions during the meeting provided venues and new opportunities for international co-operation on these issues. Concerns about over-harvest or unregulated harvest remain in some populations but great progress has been made in achieving sustainable yields from most harvested populations.

These 12th proceedings provide an overview of the ongoing research and management activities on polar bears in the circumpolar arctic. Together with the previous eleven proceedings, they provide an historic record of the international effort in protecting polar bears from over-harvest and document more recent concerns of threats arising as a consequence of increased human activities in both the Arctic and in regions far beyond the realm of polar bears.

Funding for publication of the proceedings was provided by the Canadian Wildlife Service, Edmonton; Greenland Institute of Natural Resources, Copenhagen; U.S. Geological Survey, Anchorage; Department of Resources, Wildlife and Economic Development, Iqaluit; Norwegian Polar Institute, Tromsø; and the U.S. Fish and Wildlife Service, Anchorage.

The Editors:
A.E. Derocher
G.W. Garner
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Ø. Wiig

During the final preparations of the Proceedings of the 12th Working Meeting of the Polar Bear Specialist Group, Dr. Gerald W. Garner, co-chair of the Polar Bear Specialist Group and co-editor of these Proceedings, passed away suddenly.

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Agenda

Twelfth Working Meeting of IUCN/SSC PBSG

Oslo 3–7 February 1997

Monday 3 February 1997

- 10.00 1. Opening and administrative issues
- 1.1 Introductory remarks/comments from the hosts
- 1.2 Presentation of participants
- 1.3 Election of the meeting chairman
- 1.4 Election of secretary for recording notes from the meeting
- 1.5 Suggestions of additional topics for the meeting, adoption of final agenda
- 1.6 Production and format of published proceedings from the meeting
- 1.7 Election of ad hoc “editors” for compilation of information on status of different populations for the minutes of the meeting
- 1.8 Election of group to draft press release
2. Summary of research and status of populations by nation. Future research priorities
- 2.1. Canada
- 12.00 Lunch
- 13.00 2.2 Greenland/Denmark
- 2.3 Norway
- 2.4 Russia
- 2.5 USA

Tuesday 4 February

- 09.00 3. Summary of management by nation
- 3.1 Canada
- 3.2 Greenland/Denmark
- 3.3 Norway
- 3.4 Russia
- 3.5 USA

4. New bi-/multi-lateral agreements related to polar bears
- 4.1 Greenland-Canada (Erik Born)
- 4.2 Canada-USA (Scott Schliebe)
- 4.3 Norway-Russia (Pål Prestrud)
- 4.4 Russia-USA (Stas Belikov)

12.00 Lunch

- 13.00 5. Issues pertaining to the Agreement (Scott Schliebe)
- 5.1 Reviews of the effectiveness of implementing the Agreement
- 5.1.1 MMPA/MMC (Scott Schliebe)
- 5.1.2 Norwegian case study (Fredrik Theisen)

Wednesday 5 February

- 09.00 6. Workshop on population inventory
- 6.1 Population delineation (Mitch Taylor)
- 6.2 Survival rates (Steve Amstrup)
- 12.00 Lunch
- 13.00 6.3 Population size
- 6.3.1 Mark-recapture (Andrew Derocher)
- 6.3.2 Aerial surveys (Gerald Garner)

Thursday 6 February

- 09.00 6.4 Population modeling (Nils Øritsland, Mitch Taylor)
- 6.5 Standardisation of methodologies (Andrew Derocher)
- 6.6 Research priorities
- 12.00 Lunch
- 13.00 7 Effects on polar bears of toxic chemicals
- 7.1 Report on international survey (Ross Norstrom)

- 7.2 Report on Canadian work (Ross Norstrom)
- 7.3 Report on Norwegian work
- 7.3.1 Research on biological effects (Øystein Wiig)
- 7.3.2 Levels and biomarkers (Janneche Skåre)
- 7.5 Research priorities

- 12.00 Lunch
- 13.00 10. Report on international DNA study (Ian Stirling)
- 11. Issues handled by the Chairman 1993–96 (Red list, Action plan)
- 12. Evaluation of the future status of the PBSG. Future objectives and actions of the PBSG. Next meeting.
- 13. Election of a new chairman of PBSG.
- 14. Adoption of the compilation of status of population presented by the *ad hoc* editors.
- 15. Adoption of press release.
- 16. Closing remarks

Friday 7 February

- 09.00 8. Effects on polar bears of handling and marking (Mitch Taylor)
- 9. Effects on polar bears of climatic global change (Malcolm Ramsay)

Minutes of the 12th Working Meeting of the IUCN/SSC Polar Bear Specialist Group

Monday February 3rd 1997

Opening and administrative issues Introductory remarks

The 12th Working Meeting of the IUCN/SSC Polar Bear Specialist Group (PBSG) was called to order at 10:00 am, at the Norwegian Polar Institute, Oslo, Norway by the chairman, Ø. Wiig. A list of participants is contained in this document. A series of introductory and administrative remarks were followed by the introduction of Olav Orheim, Director of the Norwegian Polar Institute.

O. Orheim welcomed the delegates to Oslo and the Norwegian Polar Institute and then gave a brief overview of international polar bear management. He noted the first international meeting between representatives from the five "polar bear countries", to discuss the protection of polar bears, was convened in Fairbanks in 1965 and the work of this group led to the signing of the International Agreement on the Conservation of Polar Bears in Oslo in 1973. The Agreement is regarded as a very good model for international co-operation in the management of international resources. Now that the Arctic environment is under increasing pressure from toxic pollution and possible global warming, there is a continuing need for international co-operation to address these problems.

He further noted that meetings of the PBSG have allowed researchers, managers, and users (Inuit) to meet to discuss issues not only related to the Agreement but also related to polar bear research and management in general. One obvious result of the Agreement and the work of the PBSG is that bi- and multinational co-operative research are presently being done on shared polar bear populations between all five nations.

He stressed that Norway takes its obligations related to the Agreement very seriously and that the Norwegian Polar Institute is responsible for polar bear research as per the Agreement. He concluded his address by acknowledging that Norway has held the chairmanship of the PBSG since 1993, that the Norwegian Polar Institute is pleased to host the 12th Working Meeting of the PBSG and would like to host a dinner for the delegates during the meeting.

Election of meeting chairman and selection of meeting secretary

Ø. Wiig was elected meeting chairman while N. Lunn and A. Derocher were appointed as meeting secretaries.

Additional topics and adoption of final agenda

Some initial changes to the agenda were proposed: M. Ramsay's presentation on the effects of global change (Friday) was moved forward to Monday afternoon. The presentation on the effects of handling and marking on polar bears (Friday, M. Taylor) was deleted because there was no new information to report. M. Taylor requested that sex selective harvesting be added as Item 6.7 and that time should be made on Friday to discuss and finalise any resolutions.

Additional modifications to the agenda were made during the course of the meeting and these are listed here: (1) discussion of population status was moved forward to be included in the workshop on population inventory, (2) I. Stirling reported that his presentation on the International DNA study could be deleted because the work was ongoing but there was nothing further to report at this time, (3) addition of a discussion item to give direction to the editors of the proceedings of this and future meetings, (4) adoption of the new PBSG chairman was moved back in the agenda to follow the discussion on the press release.

The final agenda of the meeting (as shown above) was adopted. (NB refers to Proceedings only).

Production and format of the proceedings of this meeting

Ø. Wiig stated that to publish 600 copies at 200 pages per copy, via the IUCN, would cost approximately 5300 pounds sterling and that there would be no monetary contribution from the IUCN. In addition, we would need to deliver near camera ready copy. I. Stirling suggested that we should consider investigating alternative, cheaper routes to publish the proceedings but that it should be part of some type of series. Ø. Wiig raised the option that the proceedings could be published as part of the Norwegian Polar Institute's Meddelelser series but noted the costs were likely to be only slightly less than IUCN. A discussion followed about options for publication. The final consensus was to remain with IUCN for consistency and profile of the PBSG. It was noted that

all previous proceedings of the Working Meetings of the PBSG had been published through the IUCN. It was suggested that a distribution list for the proceedings (i.e. libraries, Institutions) be provided by each country to facilitate distribution once published. M. Taylor and M. Ramsay suggested that copies be made available to the IUCN Publications Services Unit, despite the fact that no monetary contribution will be forthcoming.

Designated editors for these proceedings were: A. Derocher, G. Garner, N. Lunn, and Ø. Wiig.

Election of ad hoc “editors” for compilation of information on status of different populations for the minutes of the meeting.

M. Taylor, E. Born, and S. Amstrup were elected as ad hoc editors for the compilation of information on the status of each population and the production of a status table for this meeting.

Election of group to draft press release

I. Stirling and S. Amstrup were elected to draft the press release.

Summary of research and status of populations by nation and future research priorities

Presentations of research and population status were presented by each nation. Only a summary of these reports are presented here, details of each presentation will be included in the Proceedings.

Norway

A. Derocher presented the Norwegian research report and reported that there was no new information on which to modify the population estimate given at the PBSG in Copenhagen in 1993. Information on population borders, population dynamics and ecology, denning areas, impacts of toxic chemicals on polar bears, population estimation, new ageing techniques, climate change, marine ecology, habitat use, toxicology, cooperative research with Greenland, Russia and the US, preliminary results from a radionuclides study, and future research directions were presented.

Resolution Committee: M. Taylor, C. Brower, S. Belikov, A. Derocher, and G. Garner to draft resolution on the need for a co-ordinated international study on radionuclides.

Russia

S. Belikov reported on the Russian-American joint research program analysing population boundaries, polar bear sea-ice relationships, and collection of material for radionuclide studies.

A. Boltunov reported on population boundaries and reported that no new information on population status since the last PBSG was collected. Contamination of the Laptev Sea from heavy metals associated with gold mining and a summary of nuclear waste disposal in the Kara Sea were provided. Limited information was available on anthropogenic contaminant inflow into the arctic seas. Disturbance and illegal hunting of polar bears was thought to have decreased in most areas although this is a problem along the Chukotka coast.

M. Stishov reported on den survey methodology and results from Wrangel and Herald Islands. Funding of future research activities was uncertain due to funding difficulties.

United States

G. Garner reported on the joint research between Russia and the US that was initiated in 1990 and which is focused on the inter-relationships between polar bears and sea ice habitat. He also reported on a pilot study on satellite telemetry and adult males. Four devices were deployed: one functioned for 1 month while the other three lasted 3.5–4 months. The transmitters should have lasted at least one year, broken antennae were suspected as the cause of the premature failures.

S. Amstrup presented an overview of research on polar bears in northern Alaska. Methods used in a project to identify terrestrial denning areas using remote sensing (Forward Looking Infrared Radar) and GIS methods were presented. Amstrup suggested these methods held promise in reducing disturbance of polar bears at maternity denning sites by the oil industry.

Effects of global change

M. Ramsay presented a summary discussing the likelihood and possible impacts of global change and discussed whether there was a need for setting up a framework of how we can measure or detect changes in the environment. He suggested that global change could be broken down into three main components: human impacts, contaminants, and global warming. In discussing contaminants, he wondered what we should be collecting to detect effects of contaminants and, if contaminant levels are decreasing and we have not yet seen effects, should we be concerned. He noted the

mean sea ice extent in the Arctic has decreased by 3% over 1978–1987 and asked all to consider what we need to collect and how we should standardise measurements between researchers and between populations to detect effects of global warming on polar bears. He stressed the need to collect data in such a manner as to allow testing of predictions pertaining to various climate change models.

Tuesday February 4th

Summary of research and status of populations by nation and future research priorities (continued)

Canada

M. Ramsay presented a summary of on-going studies based at the University of Saskatchewan that include body composition, physiology, and toxicology. M. Cattet (Univ. of Saskatchewan) was reported to be continuing his study of fasting metabolism in polar bears as part of his doctoral thesis. S. Polischuk was currently writing up her research on organochlorines for her doctorate. Ramsay summarised recent work on drugs and suggested that the combination of medetomidine and Telazol was superior to Telazol alone because of: (1) faster induction time, (2) smaller volume required which allows for smaller darts and, thus, less tissue damage and (3) medetomidine was reversible. M. Taylor enquired about disadvantages: (1) presently expensive and (2) one cub died of unexplained causes while sedated.

I. Stirling provided a summary of research by the Canadian Wildlife Service and noted that current research is changing direction from being polar bear specific to focusing on the marine ecosystem. A summary of the relationship between polar bear and seal populations, a comparison of observed changes in the Beaufort Sea and Hudson Bay ecosystems as determined by long-term studies of polar bears and seals, the historical use of maternity dens in Churchill, and an upcoming project on den selection were presented. A discussion followed on the possible uses of satellite imagery to make broad assessments and comparisons of ecosystem productivity. A. Derocher noted that seasonal differences associated with latitude may not be considered in composite satellite imagery.

M. Taylor noted that much of research in the Northwest Territories was management oriented. He summarised the results of the movement studies in the Eastern Canadian Arctic and how these helped to determine current population boundaries. Taylor also reported on the study for Health and Welfare Canada regarding the

consumption of meat of bears drugged with Telazol. Although the data show that the drugs are eliminated within 72 hours, unidentified metabolites were found. Health and Welfare Canada have stated that the meat of polar bears that have been drugged with Telazol is safe for human consumption after one year. A discussion followed about the status of the publications pertaining to the Telazol elimination study. It was noted that Health and Welfare Canada had not permitted publication of the data and publication of the results were uncertain. M. Taylor also stated that hunters can request compensation for loss of meat from bears that had been handled but that few hunters had requested such compensation.

Greenland/Denmark

E. Born reported on population studies in western Greenland and on research in northeastern Greenland with Ø. Wiig. In the latter study, eight females were instrumented with satellite collars and none moved to Svalbard. Similarly, there was no recorded general movement of bears from Svalbard across to eastern Greenland based on satellite collars and tagged animals. He suggested the possibility of several local populations along the east coast of Greenland. At least 70 bears are taken each year off the east coast which would require a population of 2000–4000 animals to be sustainable. However, at present, there is no estimate of the size of the polar bear population in East Greenland.

Norway-Russia research agreement

P. Prestrud presented background information on the Norwegian-Russian Agreement on co-operative research in the Arctic which was considered essential for developing co-operative research programs between Norway and Russia. It was negotiated in 1996 and has 5 components, one of which is directed towards polar bears: “Distribution and habitat use of polar bears and the effect of pollution on polar bears in the Barents and Kara Seas”. This project has three sub-projects: distribution and habitat use of polar bears in the western sector of the Russian arctic, genetic variation of polar bears from Svalbard and the western sector of the Russian arctic, and affects of persistent organic pollutants in the Barents and Kara Seas.

P. Prestrud reported that a White Paper was given to the Norwegian Parliament in 1996 that dealt with Norwegian Policy regarding Svalbard. In the paper it was recommended that Norway should protect and maintain the wilderness character of Svalbard and that it should be among the best managed wilderness areas of the world. The Norwegian Parliament strengthened the paper by noting that the Svalbard polar bear population

was one of the least affected populations of big carnivores left on earth and that it should be maintained as a reference population for harvested populations.

Norwegian case study

F. Theisen presented results of a case study of the 1973 International Agreement for the Conservation of Polar Bears that was undertaken by the Norwegian Polar Institute as part of the AEPS Task Force on Sustainable Development and Utilisation. An initial draft of the document was circulated in late 1995/early 1996 to signatory countries and many objections were raised during the review process, especially by Canada. In particular, the Canadian Polar Bear Technical Committee was concerned about what it deemed to be excessive anti-hunting bias because of the importance of hunting polar bears to indigenous people. Theisen stated that many of the comments were incorporated into a revised document and that a final version had been completed in February 1996. However, few members of the PBSG had seen the final version and, therefore, were not able to see how the concerns of their own or other jurisdictions were addressed. It was noted that the Norwegian Case Study was only a Norwegian perspective, did not necessarily reflect the views of the other jurisdictions, and was not being endorsed or accepted by the PBSG especially since the final version had not been reviewed.

Issues pertaining to the International Agreement

S. Schliebe reported that, in making amendments to the Marine Mammal Protection Act, the International Agreement caught the attention of the US congress. A domestic review was done and the US Fish and Wildlife Service was instructed to contact signatories to the International Agreement to solicit their views on the effectiveness of their respective implementation of the International Agreement. He further noted that there was some interest in the US to re-open the International Agreement, citing areas of US non-compliance or conflict with the Marine Mammal Protection Act. Details were provided in a submitted document.

A general discussion followed in which it was noted that the PBSG is a technical group and was not formed to re-open or re-evaluate the International Agreement. The PBSG wondered whether it was a review of the International Agreement or a review of the implementation/compliance of each signatory nation with the International Agreement that was requested. M. Taylor stated that, if any country has difficulty with the issue of compliance, then two options are available: change internal legislation so they are in compliance or officially contact the other signatory nations to re-open and

re-negotiate the International Agreement. Re-opening of the International Agreement is an issue to be dealt with at the national political level and that all jurisdictions would have to be approached formally.

Summary of polar bear management by nation

Presentations on polar bear management were made by each nation. Only a brief summary of these reports are presented here. More details of each presentation follow in the Proceedings.

Canada

N. Lunn reported that polar bear management in Canada remained under the jurisdiction of the provinces and territories together with some user groups through the settlement of land claims. Since the last meeting of the PBSG, Canada has adopted new designations for the various populations that reflect a major geographical feature rather than an arbitrary alphanumeric. For example, the Western Hudson Bay population is now designated zone WH rather than A1. Polar bears are now being hunted in Newfoundland; the quota is 4 and is administered by the Labrador Inuit Association. With the signing of co-management agreements between communities within the NWT, the Northwest Territories has had to rewrite existing Big Game Regulations, a task which has just been completed. The majority of the polar bear denning area in Manitoba has been protected with the creation of Wapusk National Park on 24 April 1996. Parks Canada is also considering new parks on Baffin, Bylot, Bathurst, and Southampton Islands as well as around Wager Bay. The Federal Government tabled endangered species legislation in October 1996 that is designed to protect species and provide for their recovery. Specifically, the legislation is directed towards species that are designated as being either endangered or threatened. Polar bears are currently listed as vulnerable by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

M. Taylor provided an overview of the status of the co-management agreements that have been developed within the Northwest Territories. The most significant new change is the development of a flexible quota system. This system was developed to ensure that the female component of the harvest is controlled within sustainable limits. 1996–1997 will be the first hunting season during which the flexible quota system will be applied. He also summarised a discussion at the 1997 Canadian Polar Bear Technical Committee meeting regarding the guided non-resident sport hunt and what was meant by 'token'. At their 1997 meeting, the PBTC unanimously agreed upon a statement regarding sustainable quotas, sport hunting, and conservation.

Resolution committee: M. Taylor to circulate statement from Canadian Polar Bear Technical Committee on conservation consequences of a guided sport hunt.

Greenland/Denmark

B. Rosing noted that polar bear management in Greenland was undergoing development. Females with cubs are protected and any take is supposed to be registered but this was only on a voluntary basis. There were no reports from Thule from 1969–1992. A new system was introduced in January 1993 whereby all hunters are personally responsible for reporting kills. Harvest data quality has not been good because Greenlanders are not used to having to report. Regulations seem to be changing frequently but it is hoped that reporting will improve. In addition, as all species harvested are reported, there is difficulty in focusing on polar bears. The Greenland Home Rule is pushing for more information. Normally, Greenlanders are against any form of quota although quotas maybe imposed on the take of beluga whales. If so, then Greenlanders may become more used to and open to the idea of quotas for other species such as polar bears. There is an interest in sports harvest of polar bears although no formal decision has yet been taken. The issue will probably be raised at an upcoming hunter seminar. There is no apparent sale of gall bladders.

Ø. Wiig raised the concern that KNAPK appears to have greater power than Greenland Home Rule because they are considering a sport hunt yet have no quota system. It was noted that, consequently, such a hunt would not conform to sound conservation practices.

Wednesday February 5th

Summary of polar bear management by nation (continued)

Norway

K. Bøkseth noted that Svalbard has been part of Norway sovereignty since 1925 and that Norwegian laws do not necessarily apply on Svalbard. Polar bears are totally protected although the Governor of Svalbard can overrule this under certain circumstances (normally problem bears). Approximately 56% of Svalbard is protected as either National Parks or as Nature Reserves. He reported on polar bear management activities in Norway and covered CITES permits issued, management changes, management philosophy and human-bear interactions. Bøkseth noted that in contrast to Canadian Parks, people were encouraged to carry firearms in Svalbard. Two humans have been killed by

polar bears on Svalbard since 1993; neither was carrying a firearm.

Russia

S. Belikov reported that polar bears are still protected by law in Russia. Permits can be issued to remove bears from the wild for zoos and circuses although this did not occur during 1993–1996. In 1995, the All-Russian Research Institute for Nature Protection prepared and forwarded to the State Committee of the Russian Federation for Environmental Protection of the Russian Federation, a proposal to change the status of polar bears in the Russian Red Data Book. Specifically, to list the Barents/Kara Seas population in Category IV (taking prohibited, unknown habitat condition) and the Chukchi/Alaskan population in Category V (taxon restored). There is concern over increasing tourism on Wrangel Island because the area was set up as a State Nature Reserve and was intended to have complete protection. However, M. Stishov noted that tourism and tourists assisted by funding and assisting den monitoring studies. In the absence of funding from the State, the denning studies must rely on support from other sources, such as tourism.

A. Boltunov reported that polar bear poaching has, in general, declined in Russia as fewer people live in the North as military and scientific bases have closed. However, there are still unsubstantiated reports of continued poaching and it is possible that polar bear parts are destined for the Asian market. The areas of greatest concern were in Dixon and Chukotka. Ø. Wiig noted and circulated copies of a Norwegian publication that documented poaching of polar bears at a Russian research station in the Kara Sea.

Resolution committee: M. Taylor, S. Belikov, N. Lunn, A. Derocher, G. Garner, and M. Stishov to draft resolution recognising the sensitivity of maternity denning areas to human disturbance.

United States

S. Schliebe summarised the 1994 amendments to the Marine Mammal Protection Act that would allow American sport hunters to bring polar bear trophies/hides from hunts in Canada back into the United States. Regulations are in the last stages of being finalised. He also reported on the harvest of polar bears in Alaska. There is currently a general downward trend in the number of polar bears taken annually from the Chukchi/Bering Seas: 1980–1990, average of 131 taken each year compared with an average of only 77 taken from 1991–1996. The Beaufort Sea harvest is stable. He also reported on a study to determine the accuracy of

reporting of the sex of harvested polar bears, 177 samples were analysed. Of the samples, 30 could not be determined due to poor sample material and 8 were of unknown sex. In the remaining sample of 139, 19 were incorrectly sexed. A variety of reasons were presented for misidentification of gender including: mixing of siblings and transcription error. Younger bears were more likely to be misidentified.

Bi-/multi-lateral agreements

Greenland-Canada

M. Taylor reported on an initial meeting that was held in January 1997 to discuss the need for an agreement on the shared Kane Basin, Baffin Bay, and Davis Strait polar bear populations. There was a consensus at that meeting that such an agreement was desirable and the necessary preliminary steps to be taken were addressed. The participants are investigating possible ways to facilitate an agreement. In Canada, it is not yet clear which parties would sign such an agreement. A preliminary work schedule was agreed upon and the planning of a second meeting, to discuss a bilateral agreement, is underway.

Canada-United States

S. Schliebe presented an overview of the implementation of the Inuvialuit-North Slope Borough Agreement and highlighted the success of this approach to improving management practice. When signed in 1988, a quota of 76 animals was divided evenly between the Inuvialuit and Inupiat (38 each). In 1995, the quota for the Inuvialuit was increased by one to 39. Over the eight years that this agreement has been in effect, the Inupiat have taken 264 bears (maximum limit was 304). Overall, about 66% of the harvest had sex information with a 3:1 male:female sex ratio. The average harvest of females (10) was below the guideline (12.5). Schliebe discussed various reasons for an apparent decline in polar bear harvest, citing loss or reduction in hunting activities of the primary polar bear hunters due to age or lack of demand for products. Stirling commented that the Agreement was working well from the Inuvialuit perspective and summaries of that harvest are in the Canadian management report.

Russia-United States

S. Belikov reported that, since the early 1990s, the native communities in Chukotka have applied to both Federal and Regional authorities for a resumption of polar bear hunting. The argument for a resumption is based on the observations of an increase in the frequency of polar bear/human encounters, that the

population is at least stable if not increasing, and that polar bear hunting is very important both culturally and economically to these communities. Both Russia and the US have begun to develop a co-ordinated approach to management of this population. Each country has developed their respective versions of a bilateral agreement and a final version, acceptable to both sides, is still being negotiated. Draft copies of both the Russian and American versions of such an agreement were provided. E. Born asked whether there was any value in a resolution from the PBSG, recommending consideration of the protection of females with cubs of all ages, at this stage of the negotiations. This stimulated a discussion of what, specifically, is meant by the requirement for 'sound conservation practices' in the Agreement.

Resolution committee: E. Born, M. Taylor, S. Amstrup, S. Schliebe and S. Belikov to draft resolution on defining sustainable management and conservation measures.

Population inventory workshop

Population modelling

N. Øritsland presented a short overview of modelling polar bear population ecology. He noted that, to date, most of the population work done on polar bears has been fairly straightforward assessment work (e.g. population size, boundaries, demographic rates, and safe levels of sustainable harvest). Consequently, modelling of polar bears has not developed much past straightforward numeric models. Modelling that would enable examination of other important issues, such as minimum population size, stochasticity, effects of harvest, and environmental fluctuation remains largely unstudied in polar bears. In addition, ecological modelling of polar bears has not been developed in the way it has for other species; the preliminary Stirling and Øritsland model of the relationship between polar bears and ringed seals represents only a simple beginning. He further stressed the importance of developing a standardised set of population parameters to allow comparison of various population models and suggested that the PBSG consider setting up a "Standard Polar Bear Population". Discussion would be needed to determine what parameters to include in a "Standard Polar Bear Population" or if there should be more than one such population to represent different ecological situations.

M. Taylor presented an outline of a new model for ursid population dynamics being developed in cooperation with Marty Obbard (Ontario Ministry of Natural Resources) and ESSA consultants. The program is to be Windows based and flexible such that the user will be able to alter key parameters for all classes or just certain ones. Development copies of the model were made

available with a final version expected by summer 1997. He noted that both “good” and “bad” data will provide answers in modelling which makes management decisions difficult. The use of stochastic models allows for the estimation of confidence intervals and should aid in making management decisions.

N. Øritsland noted that NATO Advanced Research Studies guidelines were a useful approach to developing concrete programs on complex issues.

Population delineation

M. Taylor discussed the importance of objective methodology in delineating populations. Discriminant analysis was first tried but this did not prove to be too successful. Cluster analysis has been used most recently and is the method that has been used by the NWT in delineating populations in the Eastern Canadian Arctic. A modal location for all satellite fixes for one bear is used (i.e. 100 locations for 1 bear are boiled down to one modal location). Modal locations for all bears are then analysed and % contours constructed. Boundaries can then be estimated from the overlap of these contours. It is very important that methodologies be fully explained so comparisons can be made more easily.

Survival rates

S. Amstrup lead a discussion on estimating survival rates of polar bears using radio telemetry collars. Last year he had worked with Canadian Wildlife Service data and got similar results to those he reported in his paper. At that time, he also suggested to others that a pooled database on survival of bears fitted with satellite collars be developed. M. Taylor raised concern that excessive truncation of lost radios would lead to over-estimation of survival rates. At the 1997 Canadian Polar Bear Technical Committee meeting, F. Messier also expressed a willingness to help co-ordinate a database on the survival of satellite collars. The PBSG agreed to pool all available data and establish a satellite collar database to estimate survival rates. It was decided that the database should be co-ordinated through S. Amstrup and F. Messier.

Thursday February 6th

Population inventory workshop (continued)

Mark-recapture

A. Derocher lead a discussion on issues pertaining to mark and recapture models applied to estimating population size and survival rates. In his introduction, he suggested that, as a group, we were not necessarily working

with the best people in the field when analysing data sets. Concerns raised were problems associated with inadequate sample sizes, female biased population definition (based on satellite collars), temporary emigration (impacts of capture heterogeneity), unequal survival of marks, and development of new models that incorporate both recaptures and harvest returns.

A. Derocher suggested that sample sizes required can be easily modelled with the software POPAN-4. Four programs on the “cutting edge” were identified: POPAN, SURPH, SURGE, and MARK. Many mark recapture and power analysis software programs are available at sites on the Internet.

A. Derocher briefly discussed the use of transponder chips as a means of identifying polar bears. These would allow for the identification of a bear without needing to handle the animal more than once. However, it would probably require a collective effort to advance the research and development of transponder chips for polar bears.

In the discussion that followed, M. Taylor noted that the application of Jolly-Seber type models may not fit polar bears studies and recommended that the use of a Fisher-Ford model was more appropriate. He also noted that most experts are coming from a quantitative perspective not a field perspective and that, in fact, we should be looking for more robust models rather than more powerful ones. Others commented that it was important to evaluate which model is best for polar bears before one begins discussing required sample sizes for a study.

It was agreed that none present at the meeting were experts on mark and recapture models and that many jurisdictions faced similar problems. It was proposed that a workshop on mark and recapture methods, as applied to polar bears, be arranged with those more familiar with model development and the practical constraints of field conditions. It was stressed by all that it is critical that the workshop be well focused and well prepared beforehand if anything useful is to be developed.

Aerial surveys

G. Garner provided an overview of the results of a pilot study of the application of aerial surveys to estimating polar bear density and subsequently population size. The survey was to be conducted during the late summer when the ice edge was well defined. The method was to combine a single season mark-recapture estimate, with distance sampling, and tetracycline marking. Tetracycline marking was dropped early in the program to reduce harassment to the bears and to reduce cost. The

double observer model accounted for ca. 90% of the bears. Problems identified with aerial surveys were: movement of bears in and out of the survey area, twin otter not a suitable survey platform, helicopters produced different observer sightings of bears, densities recorded were approximately half of those published by S. Amstrup, and aircraft noise might make bears harder to see (scared off well in advance) or easier to see (observer notices moving animal). Garner noted that without support from Russia, an aerial survey of the Chukchi Sea was unlikely. The cost of an ice-edge survey was ca. \$500,000 US.

Den surveys

G. Garner reported on a workshop conducted in Alaska to develop and standardise den survey methods. He commented that differences exist between Russians and Americans with respect to methods used to calculate variance. He presented results on upcoming den survey methodology to be used at Wrangel Island to develop “one time” correction factors for data already collected. Standardising methods was seen as being crucial in the future development of population monitoring methods. A discussion followed on the applicability of such methods to monitor polar bear populations and it was noted that one needs to carefully consider what is desired to be achieved from den surveys.

Standardisation of methodologies

A. Derocher noted that differences in methodologies were apparent between jurisdictions and that lack of standardisation resulted in difficulty in making cross-population comparisons. He suggested that each jurisdiction make a summary of handling techniques used and attach to future submissions to the PBSG. He indicated that he would prepare an outline which each jurisdiction could then fill out.

Sex-selective harvesting

M. Taylor mentioned that this is a new method that will be implemented for the 1996/97 hunting season in the Northwest Territories. Therefore, the first test of the new system will not occur until 1997/98 when the first adjustments, if any, would have to be made. Details of this method are in the Canadian management report. There was some discussion on what the effect of removing too many males would be. M. Taylor stated his modelling indicated that, initially, the male component would decrease but that over time it would recover because more females would be present and thus cub production would increase.

Effects on polar bears of toxic chemicals (ecotoxicology workshop)

Ø. Wiig introduced the following invited specialists to the PBSG: Aksel Bernhoft, Geir Gabrielsen, Hans Jørgen Larsen, Ross Norstrom, Erik Ropstad, and Janneche Skåre.

International survey

R. Norstrom presented an overview of the 1990 circum-polar survey of toxic chemicals in polar bears. Polar bears in three populations were noted as having high mean levels of PCBs and chlordanes: Svalbard, East Greenland, and Prince Patrick Island (Northern Beaufort Sea). Overall, the Arctic was not especially more contaminated than mid-latitudes. Marine and terrestrial species in the Arctic are approximately an order of magnitude less contaminated than equivalents from mid-latitudes. Chlordanes and PCBs were the only contaminants that appeared to accumulate in polar bears.

Report on Canadian work

R. Norstrom presented a brief history of how concern for PCB and other pollutants arose noting variation in spatial and temporal trends and concerns over toxins in the diet of native peoples. He commented that current research focused on immuno-toxicology and adrenal toxicology and that there were no future plans for a large scale sampling effort. He recommended that approximately 5 sites with samples from 10–20 adult males should be planned for the year 2000. He noted that some polar bears had toxin levels at which negative impacts could be expected. Research on toxin impacts on Vitamin A and thyroid hormones were considered important.

Report on Norwegian work

Research on biological effects

Ø. Wiig presented a summary of a recent publication on the biological effects of toxic chemicals on free-ranging polar bears in Svalbard. The study concluded that no direct measures of toxic chemical impacts on reproduction in females could be documented.

Future research directions on this front were discussed. S. Amstrup suggested that monitoring cub survival in individual females with different toxic chemical loads unlikely to yield conclusive results. For example, is cub survival affected by organochlorine levels in mothers or are organochlorine levels in mothers affected by cub survival?

Levels and biomarkers

J. Skåre presented the results of PCB levels in polar bears handled in the Russian Arctic. Levels were highest in the Kara Sea area. Skåre noted that determination of PCB levels was relatively straightforward but that determination of effects was more difficult. Relative to other species, PCB levels in polar bears were high enough to cause impacts but noted that polar bears may be more tolerant to PCB effects. Inter-specific tolerance to PCBs was noted to be very high.

R. Norstrom noted that most contamination in the Canadian High Arctic came from Eurasian sources during the winter. Movement of sea ice may be another source.

In the discussion that followed these presentations, it was suggested that captive bears be used to examine possible effects of toxic chemicals on polar bears. E. Born wondered whether it was worth collecting samples from bears in East Greenland because approximately 70 bears are taken annually. A. Derocher suggested establishing tissue banks for future use. Some tissue banks for toxicological studies are already maintained by the Canadian Wildlife Service and the US Fish and Wildlife Service.

Friday February 7th

Resolutions

Seven resolutions (attached) were prepared during the week. Each resolution was read by Ø. Wiig and was followed by discussion before the next resolution was addressed. Resolutions were reworded following considerable discussion of each. There was unanimity on all resolutions but A. Derocher noted that support for the Resolution on Conservation Consequences of Native Guided Sport Hunting under a Strict Harvest System in Canada was not to imply that Norway necessarily supported sport hunting and that support for the resolution was not to be interpreted as support for increased sports hunts.

Production of proceedings

I. Stirling noted that S. M. Uspenski had passed away and that, given his life-long dedication to polar bear research, the PBSG should consider dedicating the Proceedings of this meeting to him. The suggestion was unanimously agreed to. S. Belikov stated that he would provide a suitable photograph and that, together with I. Stirling, a brief summary of Uspenski's life and work would be written.

It was agreed that the Proceedings cannot include all the material presented at the meeting and, therefore, it would be the responsibility of each jurisdiction to reduce their contribution where possible. As senior editor, A. Derocher requested that copies of submissions be provided to him no later than 15 March.

Printing costs were agreed to be shared between participating jurisdictions. M. Taylor, I. Stirling, S. Schliebe, S. Amstrup, G. Garner, and A. Derocher all indicated that they could provide funding. E. Born could not confirm a contribution at this time but was of the opinion that he could probably find the necessary funding.

Issues handled by the Chairman 1993–96 (Action Plan)

Ø. Wiig provided copies of the latest draft of the Action Plan on the management of polar bears prepared by the IUCN/SSC Polar Bear Specialist Group. It was agreed that all jurisdictions would review and provide editorial comments directly to Øystein. In addition, the population status report presented by the ad hoc editors would be incorporated into the Action Plan to have it contain the most recent information available.

Adoption of the compilation of status of population presented by the ad hoc editors

The table to accompany the status of populations was substantially revised during discussions. The general feeling was that the table did not meet the criteria of being able to “stand alone”. Additional footnotes were suggested and revised headings were created to facilitate understanding by a wider audience. Clarification of how various values were reported was requested for harvest sex ratios and for current annual harvest. M. Taylor is to redraft the table and circulate to all members for final comment.

There was some discussion on how the PBSG should respond to populations that are showing a potential decline. However, because there is often not enough data to confirm the status of a population and because the apparent problems are being addressed by the respective jurisdictions, it was not thought to be necessary to flag such populations at this time.

Future objectives and actions of the PBSG

M. Taylor was concerned that the PBSG appears to be being bypassed by respective governments on issues that the PBSG should perhaps have been consulted on and, in some cases, issues were brought up at these meetings that some members were unaware of or had

not seen. This led into a general discussion that improved communication both within and between jurisdictions was required. The opinion of the PBSG was that wider distribution of the meeting proceedings and development of an Internet home page might help elevate the profile of the group.

Adoption of the press release

I. Stirling presented a copy of the press release and discussion followed. Discussion centred on the estimate of the world population size. A. Derocher and E. Born noted that the significant digits in the estimate did not reflect the accuracy of some population estimates and did not accurately reflect those populations which have no population estimate. A revised estimate of 22,000–27,000 was included in the press release. No estimate was given for the East Greenland population.

I. Stirling indicated that the press release should be released to both the Society for Marine Mammalogy and the International Association for Bear Research and Management for inclusion in their newsletters and this was agreed to.

Next meeting

No firm date was set for the next PBSG meeting. It was agreed, similar to the Copenhagen meeting, that the PBSG meetings should be held every 3–5 years. Given the length of the meeting it was felt that it was unwise to attach the meeting to a scientific conference. A general discussion was held and the prevailing sentiment was that too much time is spent on routine reporting of research activities and management. It was felt that circulation of management and research reports a month or so prior to the meeting would enhance the discussion of important matters and reduce the length of the meeting.

Election of a new chairman of the PBSG

Stanislav Belikov and Gerald Garner were elected as the new co-chairmen of the IUCN/PBSG.

Adjournment

The meeting was adjourned at 17.00 following the election of the chairmen.

Status of the Polar Bear

IUCN/SSC Polar Bear Specialist Group

Foreword

Under the umbrella of the Species Survival Commission two specialist groups work with bears. The Polar Bear Specialist Group (PBSG) was established in 1965 to work with the one marine species, the polar bear (*Ursus maritimus*). The Bear Specialist Group (BSG) was established in 1988, in response to conservation concerns for the terrestrial bear species. In 1992 the BSG initiated an Action Plan for Bears of the World, and invited the PBSG to participate by developing the section for polar bears. Polar bears are treated separately from the other bear species, because the management of polar bears is guided by the Agreement on the Conservation of Polar Bears (from here on called the Agreement) that was signed in Oslo, Norway in 1973 by the five polar range states (Canada, Denmark, Norway, USA, and the former USSR). The Agreement is the action plan for polar bears.

In the following materials, the background of the Agreement and how it has worked for the conservation of polar bears is presented. Most of the information in this document is taken from material presented at the February 1997 working meeting of the PBSG.

Status and Distribution

This summary of the world-wide status of polar bears is the result of discussions held at the February 1997 meeting of the IUCN/SSC PBSG and is based on the status reports and revisions given by each nation. The circum-polar distribution of polar bear populations, so far as can be determined from the data available, is given in Figure 1. Table 1 summarises the current population estimates, harvest data, and provides a qualified status determination. The world population is estimated to be between about 22–27,000 bears, of which 15,000 or more are in Canada (Table 1). Polar bears are not evenly distributed throughout the Arctic, nor do they comprise a single nomadic cosmopolitan population, but rather they occur in about 19 or so relatively discrete populations, of which 14 of those currently recognised are in or shared by Canada. Table 1, which summarises the current population estimates, harvest data, and provides a qualified status determination, and the following summaries of our current knowledge of the status of polar bear populations throughout Canada, are based on the 1997 summary of the world-wide status of the polar bear, completed by the IUCN/SSC Polar Bear Specialist Group in Oslo.

Western Hudson Bay (WH)

The distribution, abundance, and population boundaries of this population have been the subject of research programs since the late 1960s (Stirling *et al.* 1977, Derocher and Stirling 1995, Lunn *et al.* 1997, Taylor and Lee 1995). Over 80% of the adult population is marked and there are extensive records from mark-recapture studies and the return of tags from bears killed by Inuit hunters. This population appears to be geographically segregated during the open-water season, although it mixes with those of Southern Hudson Bay and Foxe Basin on the Hudson Bay sea ice during the winter and spring (Stirling *et al.* 1977, Derocher and Stirling 1990, Stirling and Derocher 1993, Taylor and Lee 1995). The size of this population was estimated to be 1200 in autumn 1995 (Lunn *et al.* 1997), and the current harvest is believed to be sustainable. The harvest sex ratio of 2 males per female has resulted in a population composition that is 58% female and 42% male (Derocher *et al.* 1997).

Southern Hudson Bay (SH)

The population boundaries are based on the observed movements of marked bears, and telemetry studies (Jonkel *et al.* 1976, Kolenosky *et al.* 1992, Kolenosky and Prevelt 1983, Stirling and Derocher 1993, Taylor and Lee 1995). The estimate of population numbers comes from a three-year (1984–1986) mark-recapture study, conducted mainly along the Ontario coastline (Kolenosky *et al.* 1992). This study also documented seasonal fidelity to the Ontario coast during the ice-free season, and intermixing with the Western Hudson Bay and Foxe Basin populations during the months when the bay is frozen over. The calculated estimate of 763 was increased to 1000 by the Canadian Polar Bear Technical Committee (PBTC) because a portion of the eastern and western coastal areas were not included in the area sampled. Additionally, the area away from the coast may have been under-sampled due to the difficulty of locating polar bears inland in the boreal forest. Thus some classes of bears, especially pregnant females, and females with cubs, may have been under-sampled. The estimate of 1000 is considered conservative, and the total harvest by the NWT, Ontario, and Québec appears to be sustainable. Discussions between these three jurisdictions on co-management and co-operative research are ongoing.

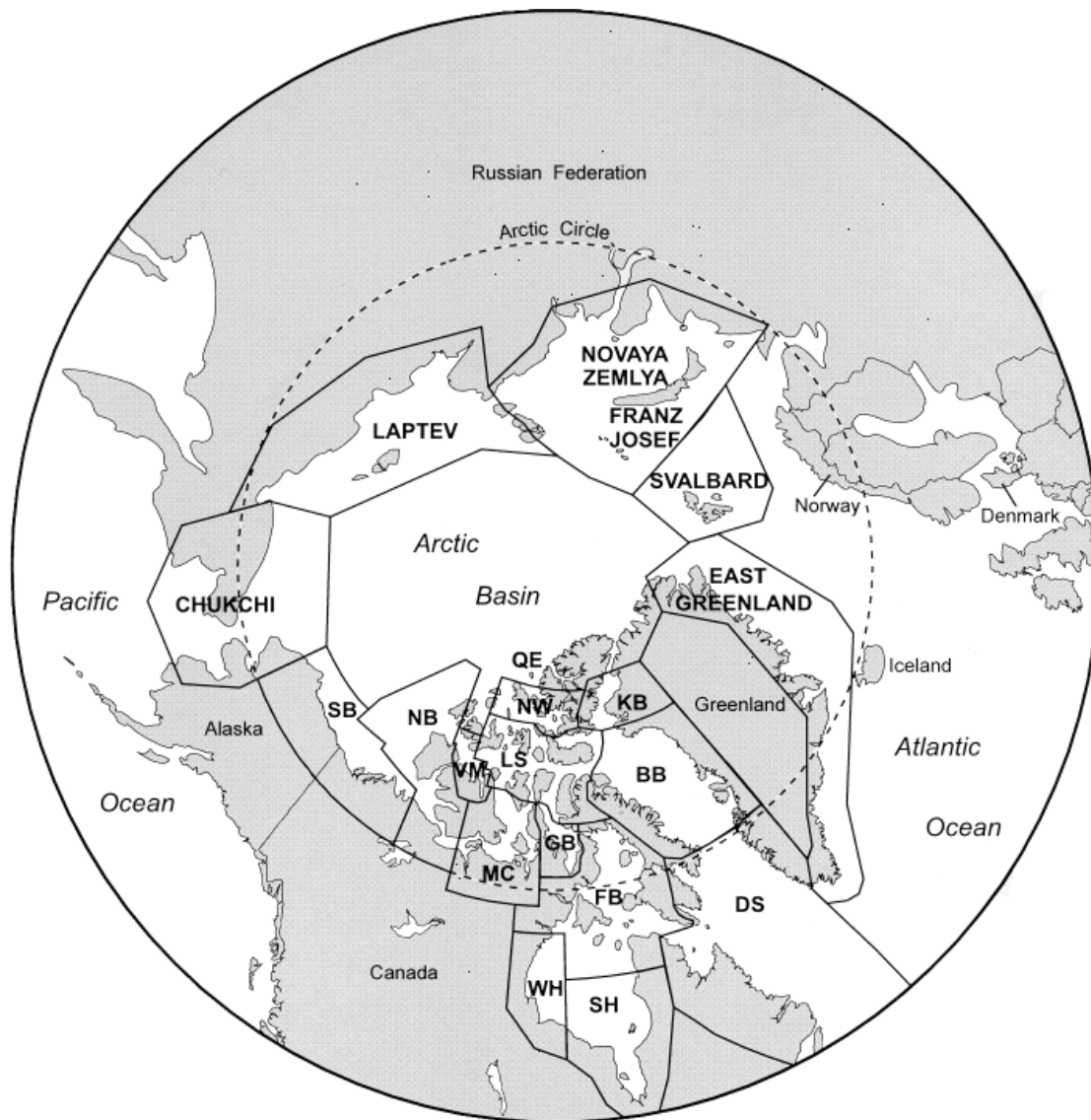


FIG. 1. Distribution of polar bear populations throughout the circumpolar basin

Foxe Basin (FB)

Based on 12 years of mark-recapture studies, a limited amount of tracking of female bears with conventional radios, and satellite tracking of adult females in western Hudson Bay, the Foxe Basin population appears to occur in Foxe Basin, northern Hudson Bay, and the western end of Hudson Strait (Taylor and Lee 1995). A population estimate based on an innovative application of biomarkers mark-recapture was concluded in 1996 (M.K. Taylor, unpublished data). During the ice-free season, polar bears were concentrated on Southampton Island and along the Wager Bay coast. However, significant numbers of bears were also encountered on the islands and coastal regions throughout the Foxe Basin area. The marking effort was conducted during the ice-free season, and distributed throughout the entire area.

The population estimate is believed to be accurate. The previous harvest quotas are believed to have reduced the population from about 3000 in the early 1970s to about 2300 (15% CV) in 1996. The harvest quota in the NWT for this area has now been revised to levels that will permit slow recovery of this population, provided that the kill in Québec does not increase. Co-management discussions with Québec are ongoing.

Lancaster Sound (LS)

The central and western portion of the area occupied by the Lancaster Sound population of polar bears is characterised by high biological productivity and high densities of ringed seals and polar bears (Schweinsburg *et al.* 1982, Stirling *et al.* 1984, Kingsley *et al.* 1985, Welch *et al.* 1992). The western third of this region (eastern

Table 1. Polar bear population status as determined by both historical harvest (1991–92 to 1995–96) levels and current management practices. The percent females statistic excludes bears of unknown sex, and natural deaths are not included.

Population	% females in harvest	Number	Sustainable Annual Kill	Mean Annual Kill	Environ. Concern	Status ¹	Quality of Estimate	Degree of Bias	Age of Estimate	Harvest / Capture Data
Western Hudson Bay	31	1200	54	44	None	S ^a	good	none	current	good (>15 yrs)
Southern Hudson Bay	35	1000	43	45	None	S ^a	fair	moderate	old	fair (5–10 yrs)
Foxe Basin	38	2300	91	118	None	S ^a	good	none	current	good (>15 yrs)
Lancaster Sound	25	1700	77	81	None	S ^a	fair	none	current	good (>15 yrs)
Baffin Bay	35	2200	94	122	None	D? ^b	fair	none	current	fair (>15 yrs)
Norwegian Bay	30	100	4	4	None	S ^a	fair	none	current	good (>15 yrs)
Kane Basin	37	200	8	6	None	S	fair	none	current	fair (>15 yrs)
Queen Elizabeth	—	(200?)	9?	0	Possible	S? ^b	none	—	—	—
Davis Strait	36	1400	58	57	None	S? ^b	fair	moderate	old	good (>15 yrs)
Gulf of Boothia	42	900	32	37	None	S ^a	poor	moderate	old	good (>15 yrs)
M'Clintock Channel	33	700	32	25	None	S ^a	poor	moderate	old	good (>15 yrs)
Viscount Melville Sound	0	230	4	0	None	I	good	none	current	good (>15 yrs)
Northern Beaufort Sea	43	1200	42	29	None	S	good	none	recent	good (>15 yrs)
Southern Beaufort Sea	36	1800	75	56	None	S	good	moderate	recent	good (>15 yrs)
Chukchi Sea	35	2000–5000	86–214	76 and poaching	None	S?				
Laptev Sea	unknown	800–1200	NA	poaching?	Possible	?	poor	unknown	old	poor (no data)
Franz Josef Land/ Novaya Zemlya	unknown	2500–3500	NA	poaching	Yes	?	poor	unknown	old	poor (no data)
Svalbard	N/A	1700–2200?	NA	incidental	Yes	S?	poor	unknown	old	good (>15 yrs)
East Greenland	50	unknown	unknown	50–100	Possible	?	NA	NA	NA	fair (>15 yrs)
Total estimate for world population size 22,000–27,000										

¹ S = stationary; D = decreasing; I = increasing; ? = indicated trend uncertain.

^a Population is managed with a flexible quota system in which over-harvesting a given year results in a fully compensatory reduction to the following year's quota.

^b See text for discussion.

Except for the VM population, the sustainable harvest is based on the population estimate (N) for the area, the estimated rates of birth and death, and the sex ratio of the harvest (Taylor *et al.* 1987):

Sustainable harvest = $\frac{N \bullet 0.015}{\text{Proportion of harvest that were females}}$. In this equation, the value used for proportion of the harvest that was female is greater of the

actual value or 0.33. Unpublished modelling indicates a sex ratio of 2 males to 1 female is sustainable, although the mean age and abundance of males will be reduced at maximum sustainable yield. Harvest data (Lee and Taylor, 1994) indicate that selection of males can be achieved.

Viscount Melville Sound) is dominated by heavy multi-year ice and apparently low biological productivity, as evidenced by low densities of ringed seals (Kingsley *et al.* 1985). In the spring and summer, densities of polar bears in the western third of the area occupied by the Lancaster Sound population are low but, as break-up occurs, polar bears move west to summer on the multi-year pack. Recent information on the movements of adult female polar bears monitored by satellite radio collars, and mark-recapture data from past years, has shown that this population is distinct from the adjoining Baffin Bay and Norwegian Bay populations (M.K. Taylor, unpublished data). A new estimate of population numbers and population status will be available in fall 1997, when the results from the final field season (spring 1997) have been compiled and reported. The current estimate of 1700 is based on a preliminary analysis of both historical and current mark-recapture data. The preliminary estimate compares favourably with a previous estimate of 1675 that included Norwegian Bay (Stirling *et al.* 1984), and was considered to be conservative. Harvest quotas for the 1996/97 were reduced to sustainable levels based on the preliminary population estimate.

Baffin Bay (BB)

Based on the movements of adult females with satellite radios and recaptures of tagged animals, the Baffin Bay population is bounded by the North Water Polynya to the north, Greenland to the east, and Baffin Island to the west (Taylor and Lee 1995, M.K. Taylor, unpublished data). A distinct southern boundary at Cape Dyer, Baffin Island is evident from the movements of tagged bears (Stirling *et al.* 1980) and recent movement data from polar bears monitored by satellite telemetry (M.K. Taylor, unpublished data). In the initial (1984–1989) study conducted in Canada (R.E. Schweinsburg and L.J. Lee, unpublished data), mark and recapture samples were collected in April and May, when most of the bears were offshore in Baffin Bay. The initial spring estimate (300–600) was based on mark-recapture data collected when capture effort was restricted to shore-fast ice and the floe edge off north-east Baffin Island. Preliminary estimates from mark-recapture sampling done during the autumn (1993–1995) open-water season suggested a population of 2200 (M.K. Taylor, unpublished data). It is clear from both analyses that sampling bias occurs when a portion of the bears are on offshore pack-ice, and unavailable to capture teams. The second study (1993–ongoing) was done in September and October, when all polar bears from this population are sampled in summer retreat areas on Bylot and Baffin islands. The results of the second year of mark-recapture sampling in 1995 were compromised by an unexpected autumn outflow of multi-year ice from Lancaster Sound, Jones

Sound, and the polar basin. This resulted in an unknown fraction of the polar bears from Baffin Bay remaining on the offshore pack-ice where they were unavailable. A preliminary estimate of 2200 is based on the 1993–1995 data, and believed to be conservative (M.K. Taylor, unpublished data). The field work for the Baffin Bay mark-recapture population assessment was completed in the fall of 1997. Completion of the Baffin Bay mark-recapture inventory is planned for fall 1997. This population is shared with Greenland, which does not limit the number of polar bears harvested. Based on the preliminary population estimate, and the most recent harvest information, it appears the population may be overharvested. Better information on population numbers and the Greenland harvest are required to clarify the status of this population. Co-management discussions between Greenland and Canada were initiated in February 1997.

Norwegian Bay (NW)

The Norwegian Bay population is bounded by heavy multi-year ice to the west, islands to the north, east, and west and polynyas (Stirling 1980, 1997) to the south. From data collected during mark-recapture studies, and from satellite tracking of adult female polar bears, it appears that most of the polar bears in this population are concentrated along the coastal tide cracks and ridges along the north, east, and southern boundaries (M.K. Taylor, unpublished data). The preponderance of heavy multi-year ice through most of the central and western areas results in low densities of ringed seals (Kingsley *et al.* 1985) and consequently low densities of polar bears. Based on preliminary data from ongoing research the current estimate for this population is 100 (M.K. Taylor, unpublished data). The harvest quota for this population was reduced to four (three males and one female) in 1996 and appears to be sustainable.

Kane Basin (KB)

Based on the movements of adult females with satellite radios and recaptures of tagged animals, the boundaries of the Kane Basin population are the North Water Polynya to the south, and Greenland and Ellesmere Island to the west, north, and east (M.K. Taylor, unpublished data). Prior to 1997, this population was essentially unharvested in Canadian territory because it is distant from the closest Canadian community (Grise Fiord) and conditions for travel there are typically difficult. However, this population was harvested by Grise Fiord in 1997 and continues to be harvested on the Greenland side of Kane Basin. In some years, Greenland hunters have harvested polar bears in western Kane Basin and Smith Sound as well. Few polar bears were encountered by researchers along the Greenland coast

1995 through 1997, possibly because of intense harvest pressure there. Based on preliminary data from ongoing research (see Lancaster Sound summary), the population estimate of 200 would support a total cumulative harvest of eight per year at two males per female (M.K. Taylor, unpublished data). The current best estimate of the Greenland kill is 6 per year which is sustainable. The Canadian quota for this population is 5, and if Canadian Inuit were to harvest from this area, as they did in 1997, over-harvest and population depletion could occur. Although the habitat appears suitable for polar bears on both the Greenland and Canadian sides of Kane Basin, the densities of polar bears on the Greenland (harvested) side were much lower than on the Canadian (unharvested) side; suggesting that this population may have been larger in past years, and could be managed for increase. Co-management discussions between Greenland and Canada were initiated in February 1997 and are continuing.

Queen Elizabeth (QE)

The Queen Elizabeth or “Polar Basin” population is a geographic catch-all population to account for the remainder of northern Canada. Polar bears occur at low densities here, but systematic inventory studies have not been done. This area is characterised by heavy multi-year ice, except for a recurring lead system that runs along the Queen Elizabeth Islands from the north-eastern Beaufort Sea to northern Greenland. Perhaps 200 polar bears are resident in this area, and others are known to move through the area or use it for a portion of the year. This population is unharvested except for an occasional defence kill. Given the low numbers and low rate of reproduction that is likely, even a small amount of incidental take could cause population depletion if visitation to this remote area becomes more common.

Davis Strait (DS)

Based on the movements made by tagged animals and, more recently, of adult females with satellite radios, this population has been determined to occur in the Labrador Sea, eastern Hudson Strait, Davis Strait south of Cape Dyer, and an as yet undetermined portion of south-west Greenland (Stirling and Kiliaan 1980, Stirling *et al.* 1980 and unpublished data, Taylor and Lee 1995, M.K. Taylor unpublished data). The initial population estimate of 900 (Stirling *et al.* 1980) was based on a subjective correction from the original mark-recapture calculation of 726, which was felt to be too low because of possible bias in the sampling. In 1993, this estimate was increased to 1400 by the PBTC to account for the realisation that the bias in sampling caused by the inability of researchers to survey the extensive area of offshore pack ice was greater than had

previously been thought and, to account for additional scientific information (I. Stirling and M.K. Taylor, unpublished data) and traditional knowledge suggesting that the population has increased over the last 20 years. The principal justification for this adjustment is the observation that the annual harvest has been sustained for the last 20 years while non-quantitative observations all continue to suggest the population has increased, and there are no data to suggest the population has been detrimentally impacted by the ongoing harvest. The population estimate of 1400 was selected because that is the minimum number of animals required to sustain the observed harvest. Clarification of the status of this population will require a population inventory conducted during the open water season, and more reliable harvest information from Greenland. Within Canada this population is harvested by Inuit from the NWT, Québec, and Labrador. Co-management discussions between Greenland and Canada were initiated in February 1997.

Gulf of Boothia (GB)

The population boundaries are based on both movements of tagged bears, movements of adult females with satellite radio-collars in adjacent areas, and interpretations by local Inuit hunters of how local conditions influence the movements of polar bears in the area (Stirling *et al.* 1978, Taylor and Lee 1995, M.K. Taylor, unpublished data). An initial population estimate of 333 was derived from the data collected within the boundaries proposed for the Gulf of Boothia population, as part of a study conducted over a larger area of the Central Arctic (Furnell and Schweinsburg 1984). Although population data from this area are limited, local hunters report that numbers have remained constant or increased. The PBTC agreed to an increase in the population estimate from 333 to 900, on an interim basis pending completion of satellite tracking and mark-recapture studies, based on recognition that the central and eastern portions of the area were not sampled in the earlier study and the beliefs of local Inuit hunters about polar bear abundance in the area. The status was listed as stationary (Table 1), but this designation should be regarded as uncertain and tentative. A satellite telemetry study of movements and a mark-recapture population inventory is scheduled for 1998–2001.

M’Clintock Channel (MC)

The current population boundaries are based on recovery of tagged bears and movements of adult females with satellite radio-collars in adjacent areas (Taylor and Lee 1995). These boundaries appear to be a consequence of large islands to the east and west, the mainland to the south, and the heavy multi-year ice in Viscount Melville Sound to the north. A six year mark-

recapture population study covered most of this area in the mid 1970s (Furnell and Schweinsburg 1984). Subsequently, a population estimate of 900 was derived from the data collected within the boundaries proposed for the M'Clintock Channel population, as part of a study conducted over a larger area of the Central Arctic (Furnell and Schweinsburg 1984). More recently, local hunters have suggested 900 might be too high so the PBTC accepted a recommendation to reduce the estimate to 700. Under a local Management Agreement between Inuit communities that share this population, the harvest quota for this area has been revised to levels that will permit the population to grow slowly if the population estimate of 700 is conservative. A satellite telemetry study of movements and a mark-recapture population inventory is scheduled for 1998–2001.

Viscount Melville Sound (VM)

A five year study of movements and population size, using telemetry and mark-recapture, was completed in 1992 (Messier *et al.* 1992, 1994, M.K. Taylor, unpublished data). The population boundaries were based on the observed movements of female polar bears with satellite radio collars and movements of bears tagged in and out of the study area. The population estimate of 230 is accurate with a 14% CV (M.K. Taylor, unpublished data). Because this population occupies such a large geographic area, it was thought to be more abundant and productive at the time the original quotas were allocated in the mid-1970s. However, this area is characterised by heavy multi-year ice and low densities of ringed seals (Kingsley *et al.* 1985) and the productivity and density of polar bears was lower than was initially expected. Consequently, quotas have been reduced, and a five-year moratorium on hunting was agreed to. In 2000, harvesting will resume with an annual quota of 4 males.

Northern Beaufort Sea (NB)

Studies of movements and population estimates of polar bears in the eastern Beaufort Sea have been conducted using telemetry and mark-recapture at intervals since the early-1970s (Stirling *et al.* 1975, 1988, DeMaster *et al.* 1980, Lunn *et al.* 1995). As a result, it was realised that there were separate populations in the North and South Beaufort Sea areas and not a single population as was suspected initially (Stirling *et al.* 1988, Taylor and Lee 1995, Amstrup 1995, Bethke *et al.* 1996). The density of polar bears using the multi-year ice of the northernmost area was lower than it was further south. The population estimate of 1200 (Stirling *et al.* 1988) is believed to be unbiased and the current harvest appears to be within sustainable limits.

Southern Beaufort Sea (SB)

The southern Beaufort Sea population is shared between Canada and Alaska (Amstrup *et al.* 1986, Amstrup and DeMaster 1988, Amstrup and Gardener 1993, Amstrup 1995, Durner and Amstrup 1995, Stirling *et al.* 1988, Taylor and Lee 1995). Mark-recapture (DeMaster *et al.* 1980) and studies of movements using telemetry (Amstrup 1995, Durner and Amstrup 1995) have been conducted semi-continuously since the late 1960s in Alaska and the early 1970s in Canada (DeMaster *et al.* 1980, Amstrup *et al.* 1986). The eastern and northern boundaries of this population have been determined from movements of marked bears and from telemetry (Stirling *et al.* 1988, Amstrup 1995). The western boundary, shared with the Chukchi population, is less clear at this point (Cronin *et al.* 1990). The population estimate of 1800 is believed to be reliable, but is confounded by uneven sampling in Alaska and Canada in different years resulting in non-random capture (Amstrup and Durner 1995). A management agreement for this area was developed by the Inupiat (Alaska) and the Inuvialuit (Canada) who harvest this population (Nageak *et al.* 1994). The current harvest appears to be within sustainable limits (Amstrup *et al.* 1986, Amstrup and Durner 1995), and local hunters feel the population has been increasing slowly.

Svalbard

The population estimate for the Svalbard area includes the western Barents Sea. Both movement and population studies using telemetry and mark-recapture have been conducted in the Svalbard area at intervals beginning in the 1970s (Larsen 1972, 1986, Wiig 1995a). Studies using telemetry indicate that some polar bears associated with Svalbard are very restricted in their movements but bears from the central Barents Sea move widely between Svalbard and Franz Josef Land (Wiig 1995a, Derocher and Wiig unpubl. data). Extent of overlap between Svalbard and East Greenland populations are unknown but there is evidence that the overlap is less significant than the sharing with Franz Josef Land (Born *et al.* 1997). The population estimate is based on ship surveys and den counts in the early 1980s (Larsen 1972, 1986). This area is currently unharvested with the exception of bears killed in defence of life and property (Gjertz *et al.* 1993, 1995, Gjertz and Persen 1987). The population associated with Svalbard was depleted by over-harvest but a total ban on hunting in 1973 allowed the population to increase (Larsen 1986). Trend information after the mid-1980s is lacking (Derocher 1996). High levels of PCBs have been detected in a sample of polar bears from this area which raises the concern that industrial activity and contaminants may cause environmental degradation (Skåre *et al.* 1994, Bernhoft *et al.*

1997, Norstrom *et al.* 1997). Heavy metal levels have been assessed but do not appear to present a threat (Norheim *et al.* 1992). Oil exploration in polar bear habitat may increase in the near future (Griffiths *et al.* 1987, Hansson *et al.* 1990). Interaction with oil exploration are most likely to occur along the marginal ice zone where the density of polar bears is known to be high (Wiig and Bakken 1990, Wiig 1995b).

East Greenland

No population inventories have been conducted in recent years to determine the polar bear population size in eastern Greenland. Although polar bears range widely along the entire coast of eastern Greenland various studies have indicated that more or less resident groups of bears may occur within this range (review by Born 1995). Satellite telemetry and movement of marked bears indicate that the exchange between eastern Greenland and the Svalbard area is minimal (Wiig 1995a, Born *et al.* 1997).

The reported catch in eastern Greenland in 1993–1995 was about 45 polar bears per year (range: 43–49) (Born, this volume). However, for 1970–1987, an annual average of 72 bears was reported (Born and Rosing-Asvid 1989), and it was estimated that the actual kill is 80 to perhaps 100 per year (Born 1995). Despite that it increasingly has become practice that hunters from Scoresby Sound in Central East Greenland go further north to take polar bears during spring (Sandell and Sandell 1996), there is no information indicating an overall increase in hunting by East Greenlanders. Based on harvest sampling in Scoresby Sound (Rosing-Asvid and Born, unpublished data) and an interview survey in Ammassalik (Glahder 1995), the proportion of adult (= independent) females in the catch was estimated at about 0.37

Given the estimates of the proportion of adult females in the catch and an average annual catch of 80 (100) bears a population of a minimum of 2000 (2500) polar bears is needed to sustain the harvest. The number of animals in the harvested population(s) is unknown.

Chukchi Sea

Tagging of polar bears for the purpose of estimating population size using mark-recapture in the eastern Chukchi Sea, based from the Alaskan coast, have been conducted at intervals since the late 1960s. However, co-operative studies between USA and Russia, using telemetry to study movements, have confirmed that polar bears in the area are widely distributed on the pack ice of the northern Bering, Chukchi, and eastern portions of the East Siberian seas (Garner *et al.* 1990,

Garner *et al.* 1994a, Garner *et al.* 1994b, Garner *et al.* 1995). Consequently, shore-based mark and recapture studies cannot be used to estimate population size. The estimates given are based on observations of dens and are considered uncertain (Chelintsev 1977, Belikov *et al.* 1986, Stishov 1991a, 1991b). This population is believed to have increased after the level of harvest was reduced in 1972. Legal harvesting activities are currently restricted to Inuit in Western Alaska and appear to be sustainable at current levels. However, recent reports of illegal harvest in Russia is cause for concern, particularly because the magnitude of this illegal kill is not known. Legal harvest rates have remained approximately constant, and polar bears are abundant in the Chukchi Sea; however, the unknown rate of illegal take makes the stationary designation uncertain and tentative.

Laptev Sea

The Laptev population area includes the western half of the East Siberian Sea, the entire Laptev Sea, including the Novosibirsk and Severnaya Zemlya Islands. Telemetry data from the East Siberian and the Chukchi Seas support the eastern boundary (Belikov *et al.* in press). Recent telemetry data from the Kara and Laptev Seas indicate the western boundary is probably Severnaya Zemlya, but data analyses are incomplete. The estimate of population size for the Laptev Sea is based on aerial surveys and den counts (Kischinski 1969, Belikov and Randala 1987, Uspenski 1989, Belikov *et al.* 1991, Belikov and Gorbunov 1991, Belikov 1993). The population estimate should be regarded as preliminary. Reported harvest activities here are limited to defence kills and a small but unknown number of illegal kills. The population is not thought to be impacted by current harvest levels.

Franz Josef Land/Novaya Zemlya

This population includes eastern portions of the Barents Sea, the Franz Josef Land archipelago, and the Kara Sea, including the Novaya Zemlya archipelago. The information for the Kara and Barents Seas in the vicinity of Franz Josef Land and Novaya Zemlya, is mainly based on aerial surveys and den counts (Parovshikov 1965, Belikov and Maeteev 1983, Uspenski 1989, Belikov *et al.* 1991, Belikov and Gorbunov 1991, Belikov 1993). Studies of movements, using telemetry, have been done throughout the area but data analyses to define the boundaries are incomplete. More extensive telemetry studies in the Svalbard area also suggest that the population associated with Svalbard could be regarded as geographically distinct (Wiig 1995a). The population estimate should be regarded as preliminary. Reported harvest activities have been limited to defence

kills and a small but unknown number of illegal kills. The population is not thought to be impacted by current harvest levels. However, contaminant levels in rivers flowing into this area and recent information on nuclear and industrial waste disposal raise concerns about the possibility of environmental damage.

Population and Habitat Threats

Both historically and currently the main threat to polar bears is over-harvesting. The life strategy of polar bears relies on high rates of adult survival to mitigate the impacts of environmental extremes in any given year. Poor cub survival and poor mating success in a given year have little impact on long term population dynamics so long as bears survive and produce cubs when conditions allow. Delayed age of first reproduction and extended parental care require high adult survival for this species to maintain itself. Further, reductions in recruitment from environmental contamination or other habitat degradation make polar bear populations even more vulnerable to depletion from direct mortality.

The extent to which human activities, such as shipping, seismic exploration, drilling, hard mineral mining offshore or onshore, transport of oil, and ecotourism might affect polar bear habitat is not known. Also, contamination of ice, water, food species, and bears themselves by oil and other toxins may increase as human activities in the Arctic increase. Preliminary assessments of these problems have been summarized by Øritsland *et al.* (1981) and Stirling (1990).

Hunting

Polar bears are harvested throughout most of their range. The numbers taken are regulated by quota in most of Canada, however there are no legal limits to the number taken by Inuit in Québec, Greenland and Alaska; or Indians in Ontario. A user group management agreement for polar bears of the Southern Beaufort Sea establishes harvest quotas. These quotas have been effective although they lack the force of law in Alaska. Although harvesting is prohibited in Russia, enforcement and current economic conditions have made it difficult to determine the extent of illegal harvest activities there. In the Svalbard area, polar bears are protected from all forms of harvest except defense kills. An important habitat consideration is direct mortality resulting from the proximity of people to bears. Defense kills are inevitable when polar bears and people occur together, although their numbers can be reduced with proper precautions and training. Mortality from set-guns and hunting from ships and aircraft have ceased as a result of the International Agreement. Harvest activities (both number taken and sex ratio) must be closely

monitored to ensure that the populations that are harvested by non-regulated subsistence hunters remain sustainable.

Petroleum Exploration

Human activities, particularly those related to oil and gas exploration and development, pose several risks to polar bears and their habitat: (1) death, injury, or harassment resulting from interactions with humans; (2) damage or destruction of essential habitat; (3) contact with and ingestion of oil from acute and chronic oil spills; (4) contact with and ingestion of other contaminants; (5) attraction to or disturbance by industrial noise; (6) harassment (disturbance) by aircraft, ships, or other vehicles; (7) increased hunting pressures; (8) indirect food chain effects due to the impacts of oil and gas-related activities on the food web upon which polar bears depend and are a part; and (9) mortality, injury, and stress resulting from scientific research to determine possible effects of oil and gas activities on polar bears and other species. Available information is not sufficient in many cases to accurately assess and determine how to avoid or mitigate possible direct and indirect effects of industrial activities. Experiments on the effects of oil contamination on polar bears showed that individuals exposed to oil will probably die.

Toxic Chemicals

Although polar bears have a greater ability to metabolize certain PCB congeners than their prey, surprisingly high PCB levels have been detected in this top predator. A comprehensive survey of chlorinated hydrocarbon contaminants (CHCs) and heavy metals in polar bears in the NWT, Canada, showed that the level of most CHCs, especially chlordane compounds, had increased from 1969 to 1984 in Hudson Bay and Baffin Bay bears (Norstrom 1990). This initiated an international survey of CHCs in polar bears where samples were collected in 1990–91 by members of the PBSG from Canada, USA, Greenland, and Norway. As previously found, the major residues in all areas were PCBs and chlordane-related. Dieldrin, hexachlorocyclohexane and chlorobenzene levels were usually an order of magnitude lower. Mean total PCB concentrations ranged from a low of approximately 2 ppm in the western North American arctic to a high of 15–20 ppm in eastern Greenland and Svalbard (Norstrom 1995). The high level of PCBs in polar bears from Svalbard were also found by Norheim *et al.* (1992). Levels in Baffin Bay and Hudson Bay areas were generally intermediate at 3–5 ppm. Thus, there appears to be a trend for levels to increase from west to east, with a substantial jump going from the Baffin Bay to the Atlantic sites. However, a more recent study incorporating additional samples indicated PCB

concentrations from Svalbard, East Greenland, Prince Patrick Islands (Canadian archipelago) were similar (Norstrom *et al.* 1998).

These data imply that most contaminants are quite evenly distributed at arctic and sub-arctic latitudes in the northern hemisphere. The significantly higher levels of PCBs in north Atlantic areas than Hudson and Baffin Bays indicates that European, possibly Eurasian, sources are major contributors in this area. The chemicals are most likely transported by high level atmospheric currents.

It is difficult to evaluate potential effects of organochlorine pollutants (OCs) in nature. For more than 20 years, most studies have been concentrated on the determination of occurrence and levels of selected organochlorines in different biota. Currently recorded levels of environmental pollutants in the Arctic reveal a further need for monitoring programs on the input from long range transport of organochlorines to this fauna.

Nuclear Waste

Concern has been expressed about the possible detrimental effects on the arctic marine ecosystem of nuclear waste dumping in the vicinity of Novaya Zemlya and other areas in the Russian Arctic. Near Cape Thompson, Alaska, low level nuclear waste was buried at the completion of a test project. Distribution of radioactivity within the polar basin and its possible effects on the food web supporting polar bears are unknown.

Global Warming

Concern is expressed about the possible detrimental effects of climatic warming on polar bears (Stirling and Derocher 1993). Current models project the first and most significant effects will be detected at high northern latitudes and this will likely reduce the extent of sea ice. If the models are correct, then prolonging the ice-free period will shorten the period during which polar bears in many populations are able to feed on seals, and this will cause nutritional stress. Early signs of impact would include declining body condition, lowered reproductive rates, reduced survival of cubs, and an increase in polar bear-human interactions. Eventually, the seal populations would decline if the quality and availability of pupping habitat is reduced. Rain during the late winter may cause polar bear maternity dens to collapse, causing the death of occupants. Human-bear problems will increase as the open water period becomes longer and bears fasting and relying on their fat reserves become food-stressed. Tourism based on viewing polar bears in western Hudson Bay will likely disappear. Should the Arctic Ocean become seasonally ice-free for

a long enough period, it is likely polar bears would become extirpated from at least the southern part of their range. Because the polar bear is at the top of the arctic marine food chain, and ice is an essential component of its environment, it is an ideal species through which to monitor the cumulative effects of change in arctic marine ecosystems.

Trade in Polar Bear Products

The PBSG is concerned about the sale of polar bear gall bladders because of the threat to the survival of other species of bears. It is difficult to control illegal trade while there are still legal sources. In Russia the sale of gall bladders (rumored to be priced at 0.5 million rubles each in January, 1993) is resulting in an increased illegal kill of brown bears. Polar bears could be equally vulnerable. Therefore, the PBSG has recommended that the sale of polar bear gall bladders should be prohibited. However, local hunters in some areas wish to retain the right to sell gall bladders because they represent a potential source of income. In some of these areas land claim legislation guarantees access to trade in all parts of legally harvested wildlife. Conservation education efforts to achieve a voluntary ban on trade in gall bladders has been effective in gaining the support of local hunters who in most cases are not informed about the implications of trade on other species.

Management

The International Polar Bear Agreement

In the early 1960s great concern was expressed about the increasing harvest of polar bears. When the first international meeting between representatives from the five "polar bear countries" to discuss protection of polar bears was convened in Fairbanks in 1965, there was little management in effect except for the USSR where polar bear hunting was prohibited in 1956 (Prestrud and Stirling 1994). At this meeting the following points were agreed upon:

1. The polar bear is an international circumpolar resource.
2. Each country should take whatever steps are necessary to conserve the polar bear until the results of more precise research findings can be applied.
3. Cubs, and females accompanied by cubs, should be protected throughout the year.
4. Each nation should, to the best of their ability, conduct research programs on polar bears within its territory.

5. Each nation should exchange information freely, and the IUCN should function to facilitate such exchange.
6. Further international meetings should be called when urgent problems or new scientific information warrants international consideration.
7. The results of the First International Scientific Meeting on the Polar Bear should be published.

Following the first international meeting on polar bear conservation, the IUCN PBSG was formed to coordinate research and management of polar bears on an international basis. In addition, this group took on the role of developing and negotiating the Agreement on the Conservation of Polar Bears (the Agreement). That Agreement was signed in Oslo, Norway in May, 1973 and came into effect for a 5-year trial period in May, 1976. The Agreement was unanimously confirmed for an indefinite period in January, 1981.

Article VII of the Agreement stipulates that: “The Contracting parties shall conduct national research programs on polar bears, particularly research relating to the conservation and management of the species. They shall as appropriate coordinate such research with the research carried out by other Parties, consult with other Parties on management of migrating polar bear populations, and exchange information on research and management programs, research results, and data on bears taken.” To meet the conditions of Article VII of the Agreement, the IUCN PBSG meets every 3–5 years.

In Annex E to the Agreement, attention was drawn to the need for special protection of female polar bears with cubs, and for their cubs. This protection was not included in the Agreement itself (Appendix II). Annex E was considered by the PBSG in 1997, and a resolution reaffirming the need for special protection measures for adult females (Appendix II), but noting that occasional take of cubs for cultural and nutritional purposes by subsistence users did not present a conservation concern.

Existing Hunting Regulations

Canada

In most Canadian jurisdictions, the seasons, quotas, and protected classes of polar bears are enforced by law. Apart from complying with the Convention on International Trade in Endangered Species (CITES), the Federal Government has delegated their mandate for management of polar bears to the Provinces and Territories. However, the Federal Government has continued to provide both technical (long-term demographic, ecosystem, and inventory research) and administrative

(Federal/Provincial Polar Bear Technical Committee, Federal/Provincial Polar Bear Administrative Committee, and the National Database) support to the Provinces and Territories. The Provinces and Territories have the ultimate authority for management, although in several areas, the decision-making process is shared with aboriginal groups as part of the settlement of land claims. The existing quota system allows reduction of quotas in response to a decline resulting from over-hunting. The Government of the NWT and the Land Claim Boards have reduced quotas in populations where there were indications of over-harvest. In the NWT a new quota system has been adopted that takes into account both the number and sex-ratio of the harvest and defense kills for determination of quota allocations in subsequent years. In the NWT and Manitoba, all human-killed bears are removed from local quotas so the non-natural mortality is constrained to be within the calculated sustainable limits. The use of aircraft to position hunting camps is allowed, but aircraft are not allowed for spotting or hunting any big game species. Only Québec (James Bay Agreement) and Ontario do not restrict the number of polar bears that are hunted by a quota system. Labrador restricts hunting with a quota system, but does not take defense kills from the quota.

Greenland

In Greenland, the polar bear hunting regulations state that bears can be taken only by hunters who hunt and/or fish as a full time occupation and have a valid hunting license issued by the Greenland authorities. Basically, these regulations try to control hunting efforts by ensuring that polar bears are taken only by traditional means as a part of the Inuit subsistence hunting. Hence, it is forbidden to use motorized vehicles (aircraft, helicopters, snowmobiles and large vessels) for the hunting of polar bears or for transportation to and from the hunting grounds. All Greenland municipalities completely protect females with cubs up to 12 months of age. However, there are some regional differences. In all areas outside the municipalities of Avanersuaq (Thule), Upernavik, and Ittoqqortoormiit (Scoresby Sound), females accompanied by young up to 24 months of age are completely protected. The latest revision of the hunting regulations for the municipality of Tasiilaq (Ammassalik, SE Greenland) in 1992 permits the killing of polar bears between 12 and 24 months of age, and females accompanied by such young. All bears are protected in July and August (August-September in the Tasiilaq area). In May, 1988, the law was revised to permit killing of single adult male bears year round.

Norway

According to the Spitsbergen Treaty of 9 February, 1920, Norway exercises full and unlimited sovereignty over the Svalbard area. However, citizens of the countries contracting to the Treaty have the same rights as Norwegians to hunt and fish in the area and to conduct maritime, industrial, mining, and commercial operations, provided they observe the local laws and regulations.

The main responsibility for the administration of Svalbard lies with the Norwegian Ministry of Justice. Norwegian civil and penal laws and various other regulations are applicable to Svalbard as well. The Ministry of Environment deals with matters concerning the environment and nature conservation. The highest local authority in Svalbard is the Governor (Sysselmannen) who exercises jurisdictional, police, and administrative authority.

After the signing of the Agreement, polar bear hunting was forbidden in Norway. The management of polar bears on Svalbard is regulated by The Royal Decree, "Regulations concerning the management of game and freshwater fishes on Svalbard and Jan Mayen," enacted in 1978.

Russia

In Russia, the Main Administration on Biological Resources of the State Committee of Russian Federation for Environment is responsible for conservation of animals included in the Russian Red Data Book (including the polar bear). Regional Committees control the situation at the local level.

In the Russian Arctic, only Wrangel and Herald Islands have special conservation status as a place of high concentration of maternity dens and/or polar bears. Wrangel and Herald Islands were included in the Wrangel Island State Nature Reserve (zapovednik) in 1976, while the Franz Josef Land State Nature Refuge was established in 1994. Special protected areas are proposed in the Russian High Arctic: the Novosibirsk Islands, Severnaya Zemlya, and Novaya Zemlya. Within these protected areas, conservation and restoration of terrestrial and marine ecosystems, and plant and animal species (including the polar bear), are the main goals. Proposals to establish special protection measures in Novaya Zemlya and for various regions of the mainland coastline and within the "economic zone" of the Russian Arctic are also being considered.

United States

In the United States, the U.S. Fish and Wildlife Service (FWS) is responsible for conservation of polar bears under terms of the Marine Mammal Protection Act (MMPA) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The MMPA, 1972, implemented a general moratorium on all takes of marine mammals including polar bears. However, certain types of take, which is defined as to harass, hunt, capture, collect or kill, are authorized under specific conditions. Alaska Natives may harvest polar bears for subsistence purposes and for purposes of creating and selling traditional handicrafts and clothing. Quotas, seasons, and other limitations are not placed on the harvest provided that the population is within optimum sustainable levels (a range between maximum net productivity level and carrying capacity), and provided that the harvest is not wasteful. Other types of allowable "take" include those for scientific research, public display, incidental takes of small numbers of polar bears through harassment such as during oil and gas exploration or development, defense of life, and takes by Federal, State, or local officials in support of the welfare of the public or the animal.

Effective October, 1988, regulations require hunters to present hides and skulls from harvested polar bears to personnel or local assistants working with the FWS within 30 days of harvest. Skulls and hides are tagged with interlocking nylon-plastic tags. Specimens, including teeth, organ tissues, claws, and ear tags and radio collars of bears marked for research are obtained through this program. Non-compliance can result in a fine.

A local user group agreement between the Inupiat of Alaska and Inuvialuit native people of the Northwest Territories of Canada established harvest guidelines for the shared polar bear population of the Beaufort Sea. The guidelines are based upon scientific data which considers population size, sustainable yield estimates, and the sex ratio of the harvest. In Alaska, compliance with the Agreement by native hunters is voluntary. The net effect of these guidelines is that harvest levels have been below sustainable levels since 1989. A comparable agreement does not currently exist for the Chukchi and Bering Sea region although the U.S. and Russian governments are in the process of developing a treaty for the conservation of polar bears of this region.

Compliance with the International Agreement: Habitat Protection

A major weakness of the Agreement has been the lack of its use to help protect critical areas of habitat, with a

few notable exceptions occurring for some denning areas (Prestrud and Stirling 1994).

Canada

In Canada, much of the denning areas in Manitoba have recently been protected by inclusion within the boundaries of Wapusk National Park. In Ontario, some denning habitat and coastal summer sanctuary habitat are included in Polar Bear Provincial Park. Some polar bear habitat is included coincidentally in some of the National Parks and National Park Reserves in the Northwest Territories. There is no known protection for offshore areas which may be important habitat, although a proposal to drill near the shore-lead polynya system in the eastern Beaufort Sea was denied because the company could not demonstrate their ability to clean up an oil spill. One of the principal concerns was the potential for detrimental effects on polar bears. Additional habitat protection measures result from restrictions on harassment, approaching dens and denning bears, and a land use permit review that considers potential impacts of land use activities on wildlife.

Greenland

In Greenland, an area of Melville Bay has been set aside as a reserve for polar bears and the major part of NE Greenland is included in the National Park of North- and East-Greenland. It is, however, permitted for licensed hunters under certain restrictions to hunt polar bears in the National Park of North- and East-Greenland.

Norway

Approximately 50% of the land area of Svalbard is totally protected, including all major regions of denning by female bears. However, protection of habitat is only on land and to 4 nautical miles offshore. Therefore, polar bears and their habitat are unprotected in the Barents Sea. Environmental regulations based on the Svalbard Treaty claim jurisdiction only out to 4 nautical miles. Norway claims control of waters out to 200 nautical miles, but only Finland has accepted these Norwegian claims.

Russia

In Russia, the denning areas on Wrangel and Herald Islands are protected, but it is not clear if there is any protection for other areas outside the protected areas. Currently, the Chukotka Autonomous Government has petitioned the Russian Federation for the authority to administer the Wrangel Island State Nature Reserve.

United States

In Alaska, land ownership and land leasing status influence conservation and protection of polar bear habitat. The primary landowners are federal and state governments and Alaska natives. Much of the land in federal ownership is designated as National Wildlife Refuges or National Parks, although no lands have been set aside specifically for polar bear habitat. The marine environment is under federal and state jurisdiction. State of Alaska jurisdiction extends from the mean high tide level seaward three miles, and includes offshore barrier islands. Federal jurisdiction extends beyond the three mile limit. In the U.S. a variety of laws provide a legal basis for habitat protection these include but are not limited to the following: MMPA; Outer Continental Shelf Lands Act; Coastal Zone Management Act; Alaska National Interest Lands Conservation Act; and the National Wildlife Refuge System Administration Act. The matrix of land ownership and legal authorities is complex and must operate to balance the need for protection of fish and wildlife habitats as well as provide reasonable public access to these areas for activities such as shipping, oil and gas exploration, and transportation. The level of protection necessary for certain terrestrial polar bear habitat types may be greater than for others based upon their values for denning or feeding. There are debates on whether specific protection should be afforded to areas within the Arctic National Wildlife Refuge that are known to be used by polar bears for denning which coincide with areas of potential oil and gas reserves. Significantly, the Arctic National Wildlife Refuge is the prime denning area for polar bears in the U.S.

Compliance with the International Agreement: Hunting Regulations

Canada

Most of Canada's harvest occurs in the NWT. Local harvesting has been managed by developing management agreements and memorandums of understanding that specify that human-caused mortality will be less than the sustained yield. In the NWT, all family groups are protected. By special permit, dependent cubs may be taken for cultural purposes, however this hunt must be supervised by the local Wildlife Officer or the Hunters and Trappers Organization to ensure the female (mother) is not harmed. A principal area of non-compliance in Canada lies in Québec where, because of the James Bay Agreement, there are no quotas, seasons, protection of females and young, or protection of bears in dens. In past years, harvest studies in Québec have been conducted, the quality of which has recently improved. Reporting of the harvest in the Province of

Ontario is irregular and may sometimes be incomplete. Females with cubs and bears in dens are not protected. There is no enforcement of quotas in either Québec or Ontario. The Province of Manitoba allows no hunting of polar bears within its jurisdiction, and records all known mortality of polar bears from defense/deterrent activities and other causes.

Greenland

Under Article VII of the Agreement, Greenland does not currently collect good hunting statistics and share them with neighboring jurisdictions. Complete protection for polar bears is afforded in the reserve in Melville Bay, however this prohibition is not enforced and polar bears are hunted there. The Greenland hunting regulations are summarized as follows: (i) there is no quota; (ii) no motorized vehicles may be used for the hunt except boats less than 40 BRT; (iii) hunters must be citizens of Greenland and hunt or fish full time, (iv) females with cubs less than 12 months of age are offered complete protection, and (v) in all areas all bears, except adult males, are completely protected in July–August (in SE Greenland: August–September). As of 1 January, 1993, Greenland residents are required to get special permits to hunt polar bears. This regulation will allow closer monitoring of the hunt and better data to be collected.

Norway

No hunting is allowed in Norway.

Russia

Illegal harvest of polar bears is occurring in different regions of the Russian Arctic, especially the Far East (Chukotka). The magnitude of the illegal harvest is not known.

United States

In the United States, under the Marine Mammal Protection Act (MMPA) of 1972, only coastal dwelling native people are allowed to hunt polar bears for subsistence purposes. The hunt is not regulated provided that the population is within optimum sustainable levels and the take is not wasteful. If populations become depleted regulations on take may be developed. Complete harvest statistics are compiled annually. Although the use of aircraft and large ships is not specifically prohibited they are generally not used (Article IV).

Compliance with the International Agreement: Local People Using Traditional Methods

Article III (d) of the International Agreement on the Conservation of Polar Bears states that polar bears may be taken, “by local people using traditional methods in the exercise of their traditional rights and in accordance with the laws of that Party.”

Canada

In Canada, most hunting of polar bears is done by aboriginal people. Maintaining polar bear hunting as part of the subsistence lifestyle is widely viewed as being of significant cultural importance. Canada also permits Inuit guided hunting by some non-native residents and non-residents using traditional dog team methods. The hunts, undertaken by sport hunters, are included with the quota allocated for native hunting and thus, are not additive to the total. There are no restrictions on use of snow machines, except during guided non-resident sport hunts.

Greenland

In Greenland, the prohibition on use of motorized vehicles, aircraft, and large vessels when hunting polar bears was motivated by the Agreement. In fact, this is probably the most effective way to limit the number of bears killed in Greenland since there is no quota system. By law it is prohibited to guide anybody without a valid license for polar bear hunt.

Norway

Norway interprets the Agreement as limiting hunting to indigenous people. Norway has no indigenous people in Svalbard, but takes the view that the intention of the Agreement was to defer to native people for access and use.

Russia

Russia currently does not allow hunting, but if these regulations are changed in the future, they desire to limit the hunt to indigenous people. An illegal harvest of unquantified levels has begun in response to economic needs and administrative neglect of the ban on hunting. The Russian government is concerned that money would drive a market hunt, and thereby make control and regulation of the hunt problematic. The term “local” people in Russia might be interpreted by some parts of government to include Russians who have been living in polar bear areas for a period of years. There is also interest expressed by certain hunting groups in Russia to

start guiding polar bear sport hunts because of the foreign currency they would attract. There have even been some advertisements for such hunts in western countries.

United States

In the United States, all hunting is done by coastal dwelling Natives. Take by non-natives and sport hunting is not allowed, although the MMPA contains provisions to waive these restrictions provided certain determinations are made. Methods and means of native polar bear hunting are not defined or restricted. Hunting is not limited provided that populations are at optimum sustainable levels. If populations become depleted, protective regulations may be enacted. In Alaska it is technically legal for a native person to use an aircraft to hunt polar, however the use of aircraft to hunt polar bears is currently not a conservation issue. Hunting of polar bears in order to sell hides has been a non-issue since 1972 when the MMPA prohibited commercial sale of non-hand-crafted hides to non-natives.

The North Slope Borough and Inuvialuit Game Council hunter management agreement for polar bears of the Beaufort Sea contains sustainable harvest limits, seasons, prohibitions on the use of aircraft, and protection of females with cubs, their cubs, and denning bears. Although the agreement is not technically binding in the US it has operated effectively over its duration. The US and Russian governments and native organizations from Alaska and Chukotka are in the process of developing a conservation treaty for polar bears of the Chukchi and Bering Seas. A future bilateral treaty must conform to provisions of the Agreement on the Conservation of Polar Bears.

Compliance with the International Agreement: Compliance by Member Nations to Annex E

Canada

Northwest Territories — In most of the NWT, all family groups are protected. In the western three populations, cubs and females with cubs under 1.5 meters in length prior to being stretched and dried, or 1.8 meters after being stretched and dried, are protected. Conversely in the western NWT, females with cubs greater than 1.5 meters in length (this may include some 2 year old cubs) are not protected.

Denning bears are protected. Hunting season opening dates are in August, and November, and this could permit the harvest of some pregnant female bears before they have the chance to den.

Manitoba — Hunting is currently closed in Manitoba. Treaty Indians may request permission to hunt from the Minister of Natural Resources. By agreement the total quota has been set at the maximum sustainable yield, which is shared equally between Manitoba and NWT. Currently, Manitoba has loaned 19 tags to the NWT for the use of local hunters.

Newfoundland — Four bears may be taken by Labrador Inuit, and females with cubs are protected.

Ontario — Females with cubs and denning bears are not protected.

Québec — Females with cubs and denning bears are not protected, except by a voluntary hunter agreement in northern Québec.

Yukon Territories — The harvest quota is on loan to the western Northwest Territories.

Greenland

Dependent cubs older than 12 months can be taken. Females with cubs up to 2 years of age are protected outside the municipalities of Avanersuaq and Ittoqqotmiit (Scoresby Sound). During the summer, July-August, all bears are protected (during August and September specific regulations exist). Harvest statistics show that approximately 26 percent of the Thule and Scoresby Sound region kill is comprised of yearling and 2-year old cubs. Hunting in specific denning areas is prohibited.

Norway

The only legal taking of females with cubs, or of females moving into denning areas, is killing in defense of life, which is permissible under the International Agreement.

Russia

Hunting was banned in 1956. Renewal of hunting may occur in the future. As with Norway, killing in defense of life occurs at minor levels. Measures to protect bears which are in or moving to dens are unclear. Nature Reserves, such as Wrangel Island, prohibit disturbance of bears moving to or in dens. Specific covenants protecting denning areas or denning bears in non-reserve areas are not known.

United States

As previously indicated, the MMPA allows unrestricted harvest of polar bears (including females with cubs and the cubs) by Alaska coastal dwelling Natives for

subsistence purposes or to make handicrafts and clothing provided that population levels are found to be optimum and sustainable. Regulations may be developed if populations become depleted.

Denning bears are not protected by statute. The North Slope Borough and Inuvialuit Game Council Agreement for the Conservation of the Southern Beaufort Sea contains provisions calling for the protection of females with cubs, for their cubs, and for denning bears. The terms of this agreement are more restrictive than the MMPA. The agreement has no legal status in the United States or Canada, is a voluntary compliance agreement between the two native groups. Although there are no penalties for violations, the agreement has worked effectively since inception. Alaskan and Russian hunters have developed a draft user's agreement for the Chukchi Sea with the assistance of their respective governments. Negotiations are continuing with the goal of completing a signed bilateral agreement. That is consistent with the Agreement for the Conservation of Polar Bears.

The importance of the International Agreement

A primary goal of the Agreement was to limit the hunting of polar bears to sustainable levels. Because so many management changes had already been put in place during the period when the Agreement was being negotiated, there was little detectable impact immediately following it being signed and ratified (Prestrud and Stirling 1994). However, there is no doubt that the knowledge that the Agreement was being negotiated, and was likely to be successful, was a significant stimulus (Fikkan *et al.* 1993). The Alaskan harvest rate was reduced by 50% following the MMPA in 1972.

To date, the International Agreement on the Conservation of Polar Bears has been the most important single influence on the development of internationally coordinated management and research programs which have ensured the survival of polar bears (Prestrud and Stirling 1994). The Agreement is not enforceable by law in any of the countries that have signed it, a weakness that has been identified in previous reviews of international wildlife law. It has been successful in bringing the harvest of polar bears within sustainable limits for most populations, while still facilitating harvest by local people. Most of the original habitat of polar bears is still intact (although not protected) and uninhabited. The polar bear is the only bear, and probably one of the only large carnivores that still occurs throughout most of its original range.

The IUCN Polar Bear Specialist Group

The work of the IUCN/SSC PBSG has always been important to the Agreement. Initially, membership was limited to government biologists working on polar bears because one of the principal tasks was negotiation of the Agreement. After the Agreement was signed in 1973, "Invited Specialists" were included to facilitate the input of experts in fields like population dynamics and physiology. One of the reasons the PBSG has been so successful is that members have been appointed by government agencies and have usually been polar bear specialists as well. Because governments have been more directly involved in the work of this Specialist Group, they have also had a vested interest in its success. Consequently, the people going to meetings have had a fair amount of authority to make decisions and commitments.

The PBSG has no regulatory function and the main function is to promote cooperation between jurisdictions that share polar bear populations, facilitate communication on current research and management, and monitor compliance with the agreement. The PBSG is not an open forum for public participation, it is a technical group which meets to discuss technical matters which relate to the Agreement. The deliberations and resolutions adopted by the PBSG are available to the public as are the published proceedings of the meetings. They have been published in the IUCN Occasional Papers Series of the IUCN Species Survival Commission (SSC).

One strength of the group has always been its small size. Because of the relationship of the PBSG to the International Agreement, membership must reflect not only technical expertise in polar bear research and management, but also equal representation of the nations signatory to the Agreement. For this reason, each nation is entitled to designate three full members. However, in matters which require a vote (e.g. elections and resolutions), each member nation is allowed only one vote. Each nation is at liberty to independently determine their process for casting a single vote. Only government appointed members may vote. Government appointed members are chosen by their respective governments.

In addition to government appointed members, the chairman may, as per IUCN guidelines for membership in Specialist Groups, appoint five full members so long as they qualify as polar bear specialists. Full members appointed by the chair and government appointed members constitute the membership of the PBSG between meetings. The chair-appointed members are considered members until the election of a new chairman, which

occurs at the end of each meeting. In this way the number of members of the PBSG will not exceed 20.

A third category titled: "Invited Specialists" is recognized. These individuals are not considered full members, but are invited to participate in a given meeting or parts of the meeting as designated by the Chairman.

These guidelines are intended to maintain the integrity of the PBSG as a small working group of technical specialists on polar bears while still ensuring that it is responsible to the governments signatory to the Agreement, the IUCN, and the international conservation community.

The PBSG considers the Agreement to be an Action Plan for polar bears.

Specific Conservation Recommendations

According to Article II of the Agreement each contracting party "... shall manage polar bear populations in accordance with sound conservation practices based on the best available scientific data," and according to Article VII, "The Contracting Parties shall conduct national research programs on polar bears ..." and "... consult with each other on the management of migrating polar bear populations ..." These articles have been very important for stimulating governments to support applied research to answer management questions on polar bears throughout their range. This work has been coordinated through the IUCN/SSC PBSG and has resulted in dramatic improvements in conservation measures for polar bears. However, all aspects of the Agreement have not been realized in all areas. The PBSG urges the signatory governments to take action to comply fully with the Agreement (Appendix I) and all resolutions, especially the Resolution of Special Protection Measures (Appendix II). The PBSG identifies populations where the current management practices appear to be causing numbers to decline (Table 1) as priorities for research and management action.

APPENDIX I

The Agreement for the Conservation of Polar Bears

The Governments of Canada, Denmark, Norway, the Union of Soviet Socialist Republics, and the United States of America,

Recognizing the special responsibilities and special interests of the States of the Arctic Region in relation to

the protection of the fauna and flora of the Arctic Region;

Recognizing that the polar bear is a significant resource of the Arctic Region which requires additional protection;

Having decided that such protection should be achieved through coordinated national measures taken by the States of the Arctic Region;

Desiring to take immediate action to bring further conservation and management measures into effect;

Have agreed as follows:

ARTICLE I

1. The taking of polar bears shall be prohibited except as provided in Article III.
2. For the purpose of this Agreement, the term "taking" includes hunting, killing and capturing.

ARTICLE II

Each Contracting Party shall take appropriate action to protect the ecosystems of which polar bears are a part, with special attention to habitat components such as denning and feeding sites and migration patterns, and shall manage polar bear populations in accordance with sound conservation practices based on the best available scientific data.

ARTICLE III

1. Subject to the provisions of Articles II and IV, any Contracting Party may allow the taking of polar bears when such taking is carried out:
 - (a) for bona fide scientific purposes; or
 - (b) by that Party for conservation purposes; or
 - (c) to prevent serious disturbance of the management of other living resources, subject to forfeiture to that Party of the skins and other items of value resulting from such taking; or
 - (d) by local people using traditional methods in the exercise of their traditional rights and in accordance with the laws of that Party; or
 - (e) wherever polar bears have or might have been subject to taking by traditional means by its nationals.
2. The skins and other items of value resulting from taking under sub-paragraphs (b) and (c) of

paragraph 1 of this Article shall not be available for commercial purposes.

ARTICLE IV

The use of aircraft and large motorized vessels for the purpose of taking polar bears shall be prohibited, except where the application of such prohibition would be inconsistent with domestic laws.

ARTICLE V

A contracting Party shall prohibit the exportation from, the importation and delivery into, and traffic within, its territory of polar bears or any part or product thereof taken in violation of this Agreement.

ARTICLE VI

1. Each contracting Party shall enact and enforce such legislation and other measures as may be necessary for the purpose of giving effect to this Agreement.
2. Nothing in this Agreement shall prevent a Contracting Party from maintaining or amending existing legislation or other measures or establishing new measures on the taking of polar bears so as to provide more stringent controls than those required under the provisions of this Agreement.

ARTICLE VII

The Contracting Parties shall conduct national research programs on polar bears, particularly research relating to the conservation and management of the species. They shall as appropriate coordinate such research with the research carried out by other Parties, consult with other Parties on the management of migrating polar bear populations, and exchange information on research and management programs, research results and data on bears taken.

ARTICLE VIII

Each Contracting Party shall take actions as appropriate to promote compliance with the provisions of this Agreement by nationals of States not party to this Agreement.

ARTICLE IX

The Contracting Parties shall continue to consult with one another with the object of giving further protection to polar bears.

ARTICLE X

1. This Agreement shall be open for signature at Oslo by the Governments of Canada, Denmark, Norway, the Union of Soviet Socialist Republics, and the United States of America until 31st March, 1974.
2. This Agreement shall be subject to ratification or approval by the signatory Governments. Instruments of ratification or approval shall be deposited with the Government of Norway as soon as possible.
3. This Agreement shall be open for accession by the Governments referred to in paragraph 1 of this Article. Instruments of accession shall be deposited with the Depository Government.
4. This Agreement shall enter into force ninety days after the deposit of the third instrument of ratification, approval or accession. Thereafter, it shall enter into force for a signatory or acceding Government on the date of deposit of its instrument of ratification, approval, or accession.
5. This Agreement shall remain in force initially for a period of five years from its date of entry into force, and unless any Contracting Party during that period requests the termination of the Agreement at the end of that period, it shall continue in force thereafter.
6. On the request addressed to the Depository Government by any of the Governments referred to in paragraph I of this Article, consultations shall be conducted with a view to convening a meeting of representatives of the five Governments to consider the revision or amendment of this Agreement.
7. Any Party may denounce this Agreement by written notification to the Depository Government at any time after five years from the date of entry into force of this Agreement. The denunciation shall take effect twelve months after the Depository Government has received this notification.
8. The Depository Government shall notify the Governments referred to in paragraph 1 of this Article of the deposit of instruments of ratification, approval, or accession, for the entry into force of this Agreement and of the receipt of notifications of denunciation and any other communications from a Contracting Party specially provided for in this Agreement.
9. The original of this Agreement shall be deposited with the Government of Norway which shall deliver certified copies thereof to each of the Governments referred to in paragraph 1 of this Article.

10. The Depository Government shall transmit certified copies of this Agreement to the Secretary-General of the United Nations for registration and publication in accordance with Article 102 of the Charter of the United Nations.

[The Agreement came into effect in May 1976, three months after the third nation required to ratify did so in February 1976. All five nations ratified by 1978. After the initial period of five years, all five Contracting Parties met in Oslo, Norway, in January 1981, and unanimously reaffirmed the continuation of the Agreement.]

APPENDIX II. Annex E: Resolution on Special Protection Measures, and a recent related resolution from the PBSG

The conference

Being convinced that female polar bears with cubs and their cubs should receive special protection;

Being convinced further that the measures suggested below are generally accepted by knowledgeable scientists to be sound conservation practices within the meaning of Article II of the Agreement on the Conservation of Polar Bears;

Hereby requests the Governments of Canada, Denmark, Norway, the Union of Soviet Socialist Republics and the United States of America to take such steps as possible to:

1. Provide a complete ban on the hunting of female polar bears with cubs and their cubs; and,
2. Prohibit the hunting of polar bears in denning areas during periods when bears are moving into denning areas or are in dens.

Clarification of The Need For Special Protection Measures For Female Polar Bears (*see* Resolution from the 1997 PBSG Meeting)

Annex E Resolution of Special Protection Measures

<i>Country</i>	<i>Ban on Hunting Females with Cubs</i>	<i>Prohibit Hunting of Bears in Dens or During Periods When Bears are with Cubs in Denning Areas</i>
Canada	Not all jurisdictions	Not all jurisdictions
Greenland/Denmark	Yes, lack of enforcement	Yes, but lack of enforcement
Norway	Yes	Yes
Russia	Yes, lack of enforcement	Yes, but lack of enforcement
United States	No, voluntary prohibitions	No, voluntary prohibitions

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Evaluation of the Polar Bear in Relation to the 1996 IUCN Red List of Threatened Animals

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Introduction

The IUCN/SSC Polar Bear Specialist Group has been asked by the IUCN to evaluate the polar bear for the 1996 IUCN Red List of Threatened Animals. In earlier versions of the Red List the polar bear has been listed as Vulnerable. The IUCN Species Survival Commission has now revised the criteria of categories (IUCN 1994). The general aim of the new system is to provide an explicit, objective framework for the classification of species according to their extinction risk. This report presents the evaluation of the polar bear based on these new criteria.

Methods

The evaluation has been done in accordance with the criteria listed in IUCN (1994) after the method suggested by Baillie (1995).

Evaluation of criteria for Red List categories

The polar bear exists in the wild. Based on Wiig *et al.* (1995) adequate data exist to evaluate the species in relation to the listed criteria for IUCN Red List Categories.

Evaluation in relation to criteria of Critically Endangered, Endangered and Vulnerable

Criterion A. Declining population. Some populations have been over-harvested in past years, and current information suggests that some populations are still being over-utilized. However, management action to correct over-harvest is underway, and the affected populations are in no danger of depletion in the near or immediate future. Overall, the number of polar bears is thought to be stable or increasing slowly.

Therefore, Criterion A does not apply.

Criterion B. Small distribution size. The species has a larger distribution than 20,000 km².

Therefore, Criterion B does not apply.

Criterion C. Small population size. Based on a minimum total population of 21,000 polar bears (Wiig *et al.* 1995), the number of mature individuals might be less than 10,000. A continuing decline does not occur.

Therefore, Criterion C does not apply.

Criterion D. Population very small or restricted. The population estimate is larger than 1,000 individuals and the population has a circumpolar distribution.

Therefore, Criterion D does not apply.

Criterion E. Quantitative analysis. A quantitative analysis of the probability of extinction has not been conducted.

Conclusion. The polar bear does not qualify for any of the criteria of Critically Endangered, Endangered or Vulnerable and is therefore a Lower Risk taxon.

Evaluation of Lower Risk category

Criterion 1. Conservation Dependent. In the mid 1960s great concern was expressed about the increase in polar bear hunting and a possible decrease in the population size. The Soviet Union had ended polar bear hunting in 1956. Following an international meeting of polar bear specialists in 1965 several management actions came into force in other areas. Canada's first quotas were instituted in 1968. Norway stopped the set-gun kill in 1970. The U.S. Marine Mammal Protection Act ended non-native harvesting in 1972. In 1973, the International Agreement on the Conservation of Polar Bears and their Habitats was signed by Denmark, Canada, Norway, the Soviet Union, and the United States. The Agreement is regarded as a Conservation Action plan for polar bears. Based on the Agreement the polar bears in Norway were totally protected in 1973.

Although some populations have been over-harvested in past years, and current information suggests that some populations are still being over-utilized (same comment as before), it is believed that without the international Agreement and national management actions, the polar bear population would decrease, resulting in the polar bear qualifying for threatened category Vulnerable.

Therefore, the polar bear qualify for the criterion of Conservation Dependent.

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Resolutions, 12th Meeting of the IUCN Polar Bear Specialist Group

1. Co-operative management of polar bear populations

The IUCN Polar Bear Specialist Group

Recognising the need to co-ordinate research on polar bear populations shared by more than one jurisdiction (Article VII); and

Recognising the benefits to polar bear research and management already derived from co-operative efforts and the sharing of information (Article VII); and

Recognising that recent co-operative management initiatives begun in some jurisdictions, also have shown promise to enhance effectiveness of management efforts; therefore

Concludes that development of sound conservation practices for shared populations requires systematic co-operation, including use of jointly collected research and management information to develop co-operative management agreements.

2. Clarification of the need for special protection measures for female polar bears

The IUCN Polar Bear Specialist Group

Recognising that the RESOLUTION ON SPECIAL PROTECTION MEASURES appended to the 1973 Agreement for the Conservation of Polar bears urges a complete ban on hunting females with cubs and their cubs; and

Recognising the requirement for sound conservation measures identified in the Agreement for the Conservation of Polar Bears; and

Recognising that the polar bear is a significant cultural, nutritional, and economic resource for local subsistence users; and

Recognising that adult females have relatively greater reproductive value compared to other sex and age groups; and

Acknowledging that harvest management practices that accommodate the occasional take of dependent young for cultural reasons are consistent with sound conservation practices so long as the mother continues to be protected; therefore

Recommends special protection for adult females and emphasises that harvest management practices that select for males and young animals may aid in offering protection for adult females.

3. Conservation consequences of native guided sport hunting under a strict quota system in Canada

The IUCN Polar Bear Specialist Group

Noting that management of the polar bear harvest in Canada is based on the establishment of sustainable annual quotas for each population, research on population size, and demographic parameters; and

Noting that in populations where native subsistence users guide non-resident sport hunters, bears taken on such hunts are not additive to, but rather comprise part of, the total allocated quota; and

Noting that allocation of some part of a quota to sport hunting causes fewer bears to be taken because not all sport hunts result in the taking of a bear, and unsuccessful tags allocated cannot be re-used by anyone else; and

Noting that compared to the subsistence hunt, a higher proportion of the bears taken in the sports hunt are males, which provides an additional measure of protection to adult females; therefore

Acknowledges that in accordance with the best available scientific information, the allocation of some fraction of an enforced sustainable quota to native guided sport hunting in Canada is not a conservation concern.

4. Basic requirements for sound conservation practices

The IUCN Polar Bear Specialist Group

Recognising that sound conservation practices for polar bears may vary among countries from total protection to sustainable harvesting; and

Recognising that the rights of local people to harvest polar bears is identified in the International Agreement for the Conservation of Polar Bears (Article I and Article III) provided this harvest is conducted according to sound conservation practices; and

Noting that sound conservation practices for sustainable harvesting of polar bears requires accurate information on:

- (1) the number, location, sex, and age of harvested animals, and
- (2) geographic boundaries of polar bear populations, and
- (3) population number and sex-age composition, and
- (4) rates of birth and death for the population; therefore

Recommends that these data be collected for populations from which polar bears are harvested, and be used to regulate the number of animals harvested to sustainable levels.

5. Uncertainty and sound conservation practices

The IUCN Polar Bear Specialist Group

Recognising that there is uncertainty (variance) in estimates of polar bear population size, rates of sustainable harvest, and numbers taken; and

Recognising that the sizes and consequently the sustainable yields of some harvested populations are still unknown; and

Recognising that the harvest of some areas has not been systematically recorded; therefore

Recommends that management strategies and harvest levels remain conservative when the scientific data are few or suspect.

6. Minimising disturbance in polar bear concentration and denning areas

The IUCN Polar Bear Specialist Group

Recognising that there is strong public interest in viewing free-ranging polar bears exhibiting natural behaviour; and

Noting that the viewing and photographing of polar bears has already become significant in areas where polar bears congregate; and

Noting that there is strong interest in viewing and photographing female polar bears and their new-born cubs in maternity denning areas, therefore

Recommends that human activities, including research, industry, and tourism, be managed to minimise disturbance of polar bears in areas where they congregate and in maternity denning areas because excessive disturbance may have a negative impact upon polar bear survival.

7. Co-ordinated international study on the levels and effects of radionuclides

The IUCN Polar Bear Specialist Group

Recognising that radionuclide contamination in the vicinity of the Novaya Zemlya Islands resulting from former Soviet military dumping in the past and ongoing and persisting sources from nuclear power generation in and flowing into the Kara Sea; and

Recognising the potential for deleterious impacts of such nuclear contaminants on polar bears and the arctic marine food chain; and

Recognising existing baseline information on radionuclide levels in polar bears is inadequate; and

Recognising that polar bears are consumed by humans in the circumpolar arctic; therefore

Recommends that a co-ordinated international study on the levels and effects of radionuclides be undertaken on polar bears throughout their range.

Press Release

12th Meeting of the IUCN Polar Bear Specialist Group

The 12th meeting of the IUCN Polar Bear Specialist Group was held in Oslo, Norway, 3–7 February, 1997, under the Chairmanship of Dr. Øystein Wiig, Zoological Museum, University of Oslo. Scientific delegates attended, representing each of the five circumpolar nations (Canada, Greenland/Denmark, Norway, USA, and Russia) signatory to the International Agreement on the Conservation of Polar Bears. Representatives from the Greenland Home Rule Government, the Greenland Hunters and Fishermen's Association, and the North Slope Borough, Barrow, Alaska, attended as invited specialists.

The group reviewed progress on research and management of polar bears since the last meeting, held in Copenhagen, Denmark, 1993. Significant progress has been made in several areas. The extensive use of satellite tracking of female polar bears has continued and facilitated the refining of boundaries of populations in several areas or central and northeastern Canada, including those shared with Greenland. Similarly, satellite tracking of female polar bears across northern Asia and Europe, from the Chukchi Sea in the East to northeast Greenland in the west is beginning to delineate several discrete populations. Of particular importance is the finding, through the use of DNA microsatellites, that there is also a genetic basis to the separation of populations based on satellite tracking.

The results of an arctic wide survey of toxic chemicals were reported. Of the locations where fat samples have been collected from polar bears for chemical analysis, the highest levels for PCBs were found in Svalbard, northeast Greenland and the northwestern Canadian Arctic Islands. In the areas where the highest PCB concentrations have been recorded, no negative effects on the health or reproduction of the bears there have yet been noted, although further studies are planned. Concern was also expressed about the fate of radionuclides from marine dumping of nuclear wastes in the vicinity of Novaya Zemlya and possible detrimental effects on polar bears and the marine ecosystem generally.

Under the International Agreement on the Conservation of Polar Bears, countries sharing populations of polar bears are required to co-operate in research and management of those populations. A co-operative agreement between the Inupiat in Alaska and the Inuvialuit in Canada on the management of the shared population of polar bears in the southern Beaufort Sea

has been in place since 1988 and continues to function well. Similarly a preliminary draft agreement between the Governments of The United States and has been developed between Alaska and Russia and users in Alaska and Chukotka is being developed and the first discussions have taken place between Canada and Greenland to initiate the development of a co-operative management agreement for the shared polar bear populations in Kane Basin, Baffin Bay, and Davis Strait.

Hunting polar bears continues to be an important part of the culture and economy of indigenous people throughout the Arctic and their ability to do so is protected by Articles I and III of the International Agreement on the Conservation of Polar Bears. To comply with the requirement that such harvesting take place in accordance with sound conservation practices the IUCN Polar Bear Specialist Group clarified that accurate information is required on the number location, sex, and age of harvested animals; the geographic boundaries of polar bear populations; population number and sex-age composition; and rates of birth and death for the population. Population modelling suggests the harvest should not include more than about 1.5% of the total number of subadult and adult females in the population.

A review of the world-wide status of polar bear, based on available knowledge was conducted. The state of knowledge of individual populations ranges from good to very poor. In summary, the world population of polar bears was thought to be between about 22,000 and 27,000. However, in many areas, numbers are still unknown. It is also important to remember that polar bears are distributed in geographically distinct populations, each of which must be managed individually. Finally, the group noted with concern that in several areas where polar bears are hunted for subsistence purposes there are insufficient population data to ensure management within sustainable limits.

Several priorities were identified as important for future research and management. These included: organising a workshop on the estimation of population size and demographic parameters: monitoring PCB levels in polar bears near Svalbard and trying to determine whether or not they are having detrimental effects on the bears: continuing to identify the boundaries and size of populations; studying the effects of the harvest, and the effects of manipulating the sex composition of the harvest on populations; and the relationships between bears, seals, and sea ice conditions.

Polar Bear Management in Canada 1993–1996

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Since the Eleventh Working Meeting of the IUCN/SSC Polar Bear Specialist Group in 1992, there have been several changes in the management of polar bears in Canada. A summary of the regulations covering polar bear management in Canada, as of 31 December 1996, is presented in Table 1. Changes made prior to 1992 are outlined in the management reports included in the proceedings of previous working meetings of the IUCN/SSC Polar Bear Specialist Group.

The Federal-Provincial Technical and Administrative Committees for Polar Bear Research and Management (PBTC and PBAC, respectively) representing the Federal Government, two territories (Northwest Territories and the Yukon Territory), and four provinces (Manitoba, Newfoundland, Ontario and Québec), continued to meet annually to discuss research results and to make management recommendations. In recent years, four Inuit user groups (Inuvialuit Game Council, Nunavut Wildlife Management Board, Makivik Corporation and the Labrador Inuit Association) have been invited to participate as members on both the PBTC and PBAC. Research arising from the meetings of the PBTC and PBAC is outlined by Calvert *et al.* in these proceedings.

Changes in the designation of Canadian polar bear management zones

The names of the Canadian polar bear management zones changed following the 1994 meeting of the PBTC (Figure 1 and Table 2). The old system, whereby each zone was referred to by a letter or letter and number (e.g. C or E1), was inconvenient because, for most people because the letters were not as easy to associate with zones as were the geographic names. This became most apparent during community consultations to develop Local Management Agreements in the NWT. Simultaneously, information on polar bear movements greatly increased as satellite telemetry technology improved and became a routine research tool. Management zones were revised with the intention that each would be a demographic unit that could be managed independently from adjoining units. These units were termed populations although it was clear that they were not genetically isolated. The identification of each population as a Management Zone also entailed redefining the zone with a two-letter abbreviation of a major geographical feature within each population/zone (Figure 1). The changes are in name only and do not affect the populations although some of the Management Zone

Table 1. Summary of regulations covering polar bear management in Canada as of 31 December 1996.

<i>Category</i>	<i>Jurisdiction</i>					
	<i>Manitoba</i>	<i>Newfoundland</i>	<i>Northwest Territories</i>	<i>Ontario</i>	<i>Québec</i>	<i>Yukon</i>
Hunting	closed	reviewed annually: hunting permitted Feb-Jun in portion of Labrador north of Cape Harrison	varies between NWT Wildlife Management Polar Bear Areas: longest season 1 Aug-31 May; shortest season 1 Jan-31 May	closed	none	1 Oct-31 May in GMZ1 only
Who can hunt	A person who possesses a Ministerial permit	licences distributed by Labrador Inuit Association	Inuit residents and non-residents with Wildlife Certificate if HTA provides necessary tag	permissible kill by Treaty Indians	Inuit and Indians	Inuit only who are issued polar bear tags
Quota	27 (19 currently on loan to the NWT and included in the NWT total; 8 retained for the Polar Bear Alert Program)	4 (review requested)	by settlement: 1996-97 quota is 531 (including 19 loaned by Manitoba and 6 administered for Yukon)	permissible kill of 30 (by restricting sales over 30)	none	6 (all of which are presently included in NWT total)
Females and cubs protected by law	yes	females accompanied by cubs (young-of-the-year) may not be taken	yes	no	yes	yes
Bears in dens protected by law	yes	yes	yes	no	yes	yes
Proof of origin of untanned bear	documented proof	documented proof (no seal on hide implemented to date)	seal on hide and export permit	seal on hide, proof of origin required on imported hides	seal on hide	seal on hide, kill monitored by export permit
Export permit required and cost (out of province or territory of origin)	required no cost	required no cost	required: no cost. There is a \$750.00 Trophy Fee for non-residents and non-resident aliens	required no cost	required no cost	required no cost
Export permit out of Canada	required by CITES for all polar bears or parts thereof exported out of Canada; obtained from Province or Territory in which port of export					
Scientific Licences	discretion of Minister	discretion of Minister	discretion of Director of Wildlife and Fisheries, Department of Resources, Wildlife and Economic Development	discretion of District Manager	discretion of Minister	discretion of Director-Field Services Branch

Table 1. Summary of regulations covering polar bear management in Canada as of 31 December 1996 (continued).

<i>Category</i>	<i>Jurisdiction</i>					
	<i>Manitoba</i>	<i>Newfoundland</i>	<i>Northwest Territories</i>	<i>Ontario</i>	<i>Québec</i>	<i>Yukon</i>
Selling of hide by hunter	subject to conditions of Ministerial permit	yes, must be taken legally	yes must be sealed	must be sealed by Ministry staff	must be sealed; fee 5% of average value of last 2 years	permit required from Conservation Officer
Basis of Regulation	The Wildlife Act; reclassified as protected species in 1991	Wildlife Act, Chapter W-8 of The Revised Statutes of Newfoundland, 1990; classified as big game	Wildlife Act and Regulations; 1960 Order in Council (Endangered Species)	Game and Fish Act R.S.O. 1980, Chap. 182	Wildlife Conservation and Management Act 1983; Order in Council 3234-1971; Bill 28-1978 (James Bay Agreement)	Wildlife Act 1981; Wildlife Regulations
Fur Dealer Authority	\$25.00 general \$25.00 travelling	Fur Dealer's Licence: no cost	\$150.00 Fur Dealer's Licence for each of the first 2 consecutive years, then \$10.00 for each year after \$200.00 Travelling Fur Dealer's Licence for each of the first 2 consecutive years, then \$25.00 for each year after	\$28.00 licence	\$335.00 licence	\$25.00 Resident \$300.00 Non-resident \$5.00 Agent \$25.00 Non-resident restricted
Taxidermy	\$30.00 licence	yes, must be taken legally; legislation under review	\$25.00 Taxidermist Licence	see Tanner's Authority	see Tanner's Authority	\$25.00 Resident Licence \$30.00 Non-resident Licence
Tanner's Authority	\$30.00 licence	no legislation at present	\$25.00 Tanner's Licence	Game and Fish Act (\$28.00 licence)	\$256.00 Tanner's Licence	\$2.00 Resident \$10.00 Non-resident
Live Animal Capture	Ministerial permit	Ministerial permit required	\$5.00 licence to capture live wildlife	District Manager	Ministerial permit	free Wildlife Research Permit, \$5.00 fee for capture of live wildlife
Live Animal Export	Ministerial permit	Ministerial permit required	Licence to Export Live Wildlife, \$3000.00/polar bear	District Manager	Ministerial permit	Special permit

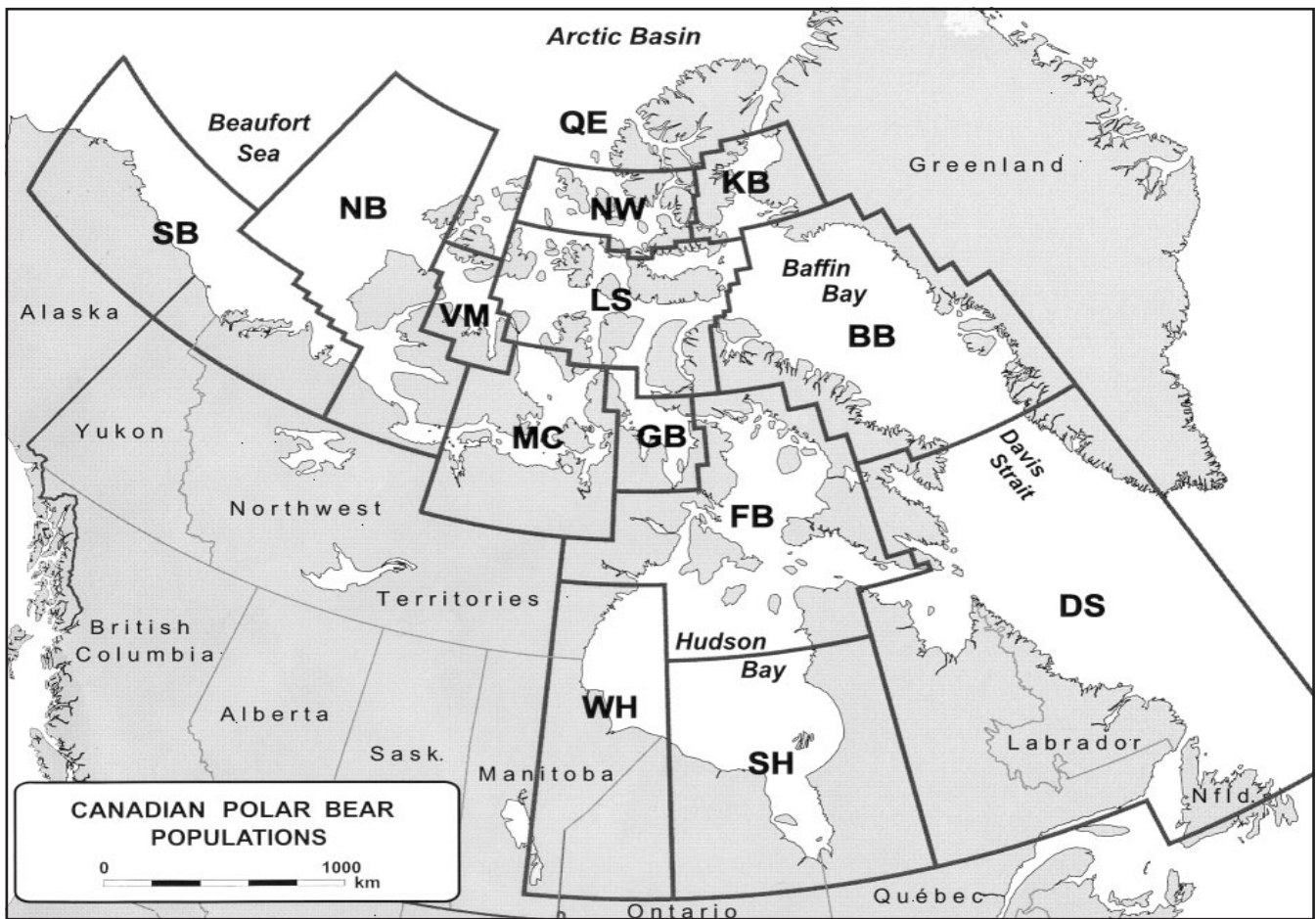


FIG. 1. Canadian polar bear management zones (two-letter abbreviations) as of 31 December 1996. See Table 2 for full name of each zone.

Table 2. Names and abbreviations of Canadian Polar Bear Management Zones as of 31 December 1996.

<i>Management Zone</i>	<i>Abbreviation</i>	<i>Comments</i>
Southern Beaufort Sea	SB	old zone H1
Northern Beaufort Sea	NB	old zone H2
Queen Elizabeth Islands	QE	old zone G, some boundary changes due to recent research
Viscount Melville Sound	VM	old zone E1
M'Clintock Channel	MC	old zone E2
Gulf of Boothia	GB	old zone E3
Lancaster Sound	LS	old zone F, some boundary changes due to recent research
Norwegian Bay	NW	part of old zone G
Kane Basin	KB	parts of old zones D1, F, and G
Baffin Bay	BB	old zone D1, some boundary changes due to recent research
Foxye Basin	FB	old zone C
Davis Strait	DS	old zone D2, some boundary changes due to recent research

Table 3. Quotas¹ and known numbers of polar bears killed² in Canada, 1991–92 through 1995–96.

	<i>Man.</i> ³	<i>Nfld.</i>	<i>NWT</i> ³	<i>Ont.</i> ⁴	<i>Qué.</i> ⁵	<i>Yukon</i>	<i>Total</i>
1991–92 quota	35	4	609	30	62	6	746
Bears killed	7	11	543	7	35	6	609
Bears captured/zoos	1	0	0	0	0	0	1
1992–93 quota	35	4	583	30	62	6	720
Bears killed	5	2	502	15	38	5	567
Bears captured/zoos	0	0	0	0	0	0	0
1993–94 quota	8	4	554	30	62	6	664
Bears killed	5	4	431	9	28	1	478
Bears captured/zoos	0	0	0	0	0	0	0
1994–95 quota	8	4	538	30	62	6	648
Bears killed	15	9	465	2	19	1	511
Bears captured/zoos	2	0	0	0	0	0	2
1995–96 quota	8	4	535	30	62	6	645
Bears killed	9	2	423	10	28	0	472
Bears captured/zoos	4	0	0	0	0	0	4
1996–97 quota	8	4	531	30	62	6	641

¹ Management year extends from 1 July to 30 June the following year. Numbers may change as more information is received from the communities.

² All known kills, including quota and sport-hunt kills, problem kills, illegal kills, bears found dead, and bears that die while being handled by scientists.

³ For 1991/92 and 1992/93, 15 of the Manitoba quota of 50 were administered by NWT. In 1993/94, the sustainable harvest of the population was estimated at 55 bears; this quota was divided evenly between the NWT (28) and Manitoba (27). Nineteen of the Manitoba quota of 27 are administered by the NWT and any kills under this loaned quota are included in the NWT total.

⁴ Permissible kill.

⁵ The total allowable kill in Québec is a maximum harvest level controlled by the length of the hunting season and by allowing only certain sex- and age-categories to be taken.

Table 4. Manitoba Polar Bear Control Program 1992–96.

	1992	1993	1994	1995	1996
No. of occurrences ¹	133	93	146	65	162
No. of bears captured	54	58	79	33	102
No. of bears killed:					
— by Department personnel	1	2	3	0	3
— by public	2	2	3	3	1
Handling deaths	0	0	8	2	3
Natural deaths	0	1	1	0	1
No. of bears sent to zoos	0	0	2	4	2

¹ all bears reported to or observed by Department of Natural Resources staff in the Churchill control zone and peripheral area.

boundaries have changed as a consequence of more recent research on the distribution of populations (Fig. 1).

Polar bear kills by jurisdiction

The quota of polar bears taken by each jurisdiction is based on recommendations by the Federal-Provincial Committees. Table 3 summarises the annual quotas and numbers of polar bears killed in 1991–92 through 1995–96 and the recommended quotas for 1996–97.

From 1990 onwards, the sustainable quotas for each population in the Northwest Territories have been divided between the communities that hunt within them. This has resulted in minor changes to the Management Zone totals from previous years. However, these adjustments simply reflect more closely the population being hunted and do not affect total quotas or kills.

Management changes and reports by jurisdiction

Manitoba

Polar bear quota

The quota for the WH Management Zone was established by the PBAC and PBTC and is shared by Manitoba and the Northwest Territories. To comply with the goals of the International Agreement on the Conservation of Polar Bears, Manitoba legislates polar bears as a protected species and the Manitoba quota is used for polar bear control in and around the Churchill townsite. For 1991/92 and 1992/93, this quota was 50 polar bears: 35 for use in Manitoba's Polar Bear Alert Program and 15 loaned to and administered by the Northwest Territories for use by communities hunting within the boundaries of the Western Hudson Bay polar bear population. This loan was based on requests by the NWT for additional tags for this population and that fewer than 50 bears were being killed in Manitoba's control program.

In 1993, the Government of the Northwest Territories negotiated a co-management agreement between all NWT communities hunting in Management Zone WH, with input from both the Canadian Wildlife Service (on sustainable harvest) and the Government of Manitoba (on division of the quota). The sustainable harvest was estimated to be 55 bears and this was divided evenly between the NWT (28) and Manitoba (27). Based on the average number of bears removed annually, which included all bears killed by Manitoba Department of Natural Resources (DNR) staff, sent to zoos, and accidental deaths while immobilised by DNR staff, Manitoba committed 8 tags to the Polar Bear

Alert Program. The balance of Manitoba's quota (19) were loaned to the NWT. Manitoba was not a signatory to the co-management agreement because it was an agreement between the Government of the Northwest Territories and NWT communities. Manitoba's quota has remained at 27 bears from 1993/94 to the present.

In 1996, Manitoba reviewed the number of polar bears removed from the population within Manitoba from 1986 through 1995 and recalculated an annual average. This average remained at 8 bears but included all human caused mortality (not just by DNR staff) and bears sent to zoos. Should a detrimental impact on the polar bear population occur due to this averaging method, Manitoba would revise its administration of the loaned quota.

Polar Bear Alert Program

The annual Polar Bear Alert Program for the Churchill townsite and surrounding area continues each autumn. The objectives of this program are to (1) ensure the safety of people and the protection of property from damage by polar bears and (2) ensure that bears are not unnecessarily harassed or killed. Program highlights are summarised in Table 4.

Wapusk National Park

The agreement to establish a national park at Churchill was signed in April 1996 and the new park named Wapusk National Park, which is Cree for white bear. The Park will encompass most of the maternity denning area but little of the area used for polar bear-based tourism. The transfer of the lands from the Provincial Crown to the Federal Crown is underway and is expected to be completed in the spring of 1997. The establishment of the Park will bring an additional management agency into the Western Hudson Bay polar bear population but is not expected to result in any changes to Manitoba's polar bear management program which is primarily directed to the Churchill Polar Bear Alert Program.

Newfoundland

There have been no changes in the management of polar bears.

Northwest Territories

Status of NWT polar bear management plan and management agreements

A draft management plan has been developed for the Northwest Territories and has been reviewed by both

the PBTC and territorial biological staff, but, has not been updated for 4 years. With the signing of the Nunavut and Inuvialuit Land Claims, the management process described in the previous management plan must be modified because the respective roles of the Government of the Northwest Territories and the Nunavut Wildlife Management Board and Inuvialuit Wildlife Management Advisory Council are defined in law and, thus, the management plan must be modified to be consistent with the Land Claim legislation. Additionally, the approach to managing polar bears has come to depend heavily on the co-operative development of Population Management Agreements with the communities. A revised version of the Polar Bear Management Plan is being considered but it may be a product of the respective Land Claim Boards rather than a product of the Department of Resources, Wildlife and Economic Development.

Currently, polar bear management begins with community meetings and concludes with Population Management Agreements that are signed by the communities that share these populations and the Minister of Resources, Wildlife and Economic Development. These agreements are then reviewed by the Land Claim Boards and then transmitted to the Minister of Resources, Wildlife and Economic Development as recommendations for regulation changes to enable the agreements. Interestingly, the development of Polar Bear Management Agreements and Memoranda of Understanding (MOU) for the purpose of developing regulations to manage polar bears has resulted in an evolutionary process that defines the issues and options. Each agreement is improved by review and new ideas from the participants. Working with communities on the language and implications for regulations also provides an opportunity to explain the need for the regulation and the realities of how polar bears are hunted. Although not every solution has worked perfectly, the process is regarded as a continuing one. However, it is worth noting that the main management changes for polar bears in the post-Land Claim environment have been increased protection for females (all family groups are now protected) and a commitment at all levels for sustainable harvesting that has resulted in quota reductions for five populations.

Other jurisdictions that share a population are encouraged to participate in this process, co-operation between jurisdictions was supported by the PBAC and inter-jurisdictional agreements have been identified as a management need for shared populations.

Population Management Agreements may change as new information becomes available or according to the preferences of local hunters. However, no changes will

occur without consultation with all affected communities and jurisdictions that share a given population.

Sex-selective harvesting

All Nunavut communities except those in Davis Strait have signed Polar Bear Agreements/MOUs which specify the number and sex ratio of the harvest (see Appendix 1). In Davis Strait the sex ratio of the harvest has not been a problem when the data were pooled for all communities and the population estimate and harvest is regarded as conservative. Thus, Davis Strait communities did not feel the flexible quota system was needed for their area at this time and continue with a single-tag, either-sex system.

Conservation education

Conservation education initiatives included community meetings to explain the flexible quota sex-selective system and meetings to develop the Polar Bear Management Agreements and MOUs. All Nunavut communities were visited and new agreements were developed for all polar bear populations within Nunavut except Western Hudson Bay which is ongoing. Meetings to develop new agreements for polar bear populations hunted by the Inuvialuit are scheduled for 24 June 1997. A translated poster and brochure explaining some features of the new agreements and MOUs were developed and circulated. The poster theme was a harvest board to assist residents in monitoring the number and sex-ratio of the harvest. Baseball caps identifying hunters who harvested male bears were prepared and will be distributed post-harvest.

Compensation for defence killed polar bears

Under the Local Management Agreements, all bears killed by human activity, not just those taken by hunters, are included in the annual quota to ensure that the overall take is sustainable. Consequently, a bear taken as a defence kill or one that died during handling by scientists, would have to have a quota tag issued by the nearest community. As this would remove potential income from hunters, a policy of compensating the HTA for the current market value of the hide has been established. In some cases, such as in the Beaufort Sea, industry has signed an agreement with the Inuvialuit that if a bear dies accidentally at an industrial site, compensation will be at the current rate for a commercial sport hunt (currently between \$16–23,000 Can). A scientific party or group of adventurers might be required to pay the current price for a good hide on the fur market. NWT is also considering a revolving fund to address compensation for legitimate defence kills if a person who kills a bear is unable to pay compensation. This fund would be

intended for those individuals who, after investigation, are shown to have acted responsibly under the circumstances.

Polar Bear deterrent studies

Efforts at research and development of new methods to deter polar bears were hampered by federal legislation and regulations on firearms, possession, and shipping of “hazardous” materials. Essentially almost any effective deterrent method for polar bears could be used on humans and, therefore, is either banned or difficult to procure and transport. Great difficulty was encountered in importing deterrent products or the materials to manufacture deterrent products. The result is a very limited potential for individuals to respond to bear attacks on life and property.

As approximately 85% of the defence kills in the Northwest Territories are due to local hunters, the current deterrent program emphasises the development of practical polar bear deterrent devices that are sufficiently portable and robust to be functional in actual camp situations. Most hunters carry a shotgun or rifle and, therefore, firearm based deterrents have been emphasised. New products that could be both practical and useful for deterring polar bears have been identified but many are classified as restricted weapons because they were manufactured for police use. Shotgun-based “scare shells”, using star shells and fire crackers, were about the only effective deterrent legally available to non-enforcement officers. These devices do scare some polar bears away but, in many instances, the bears become accustomed to the flash and the noise and subsequently return.

As reported previously, capsicum aerosols were not effective at cold temperatures and the performance of the spray was also cold dependent. In addition, aerosols had little value as a polar bear deterrent in the windy, cold conditions that prevail during most encounter scenarios in the Northwest Territories. A capsicum shell, that has been designed for shotguns and uses powdered capsicum, was located and obtained but has not been tested.

Exploding marker darts have also been tested. These darts are rubber tipped, do not penetrate the skin at any range and, when they hit, ignite flash powder which detonates with a loud bang. A superficial slap is delivered at the same time. Tests were performed for the .50 cal dart rifles only, these darts could be manufactured for use in shotguns and present some promise for long-range deterrent potential.

Capture and handling has been effective in encouraging problem bears to leave outpost camps and communities. Several Parks Canada and Renewable Resource Officers have been equipped with capture equipment which they are deploying in deterrent efforts. All problem polar bears handled ($n = 27$) left the area upon recovery which suggested that this method may be effective when trained personnel are available.

The Polar Bear Management Agreements and MOUs indicate that the Department of Resources, Wildlife and Economic Development will work with the Hunters’ and Trappers’ Organizations to develop better methods of deterring problem bears and protecting property and meat caches on the land. The Agreements and MOUs also indicate the Department and HTOs will work together to identify methods of compensating hunters that suffer losses from polar bears. The communities of Clyde River and Broughton Island on northeastern Baffin Island have a particularly large number of bear incidents during the fall open water season. Although each community has approximately the same number of polar bear encounters as Churchill, Manitoba per year, to date there has been no dedicated bear deterrent program to assist these communities.

Protection of polar bear habitat in the NWT

The NWT has recently published (1995) a preliminary summary entitled, *Wildlife Areas of Special Interest to the Department of Renewable Resources in the Nunavut Settlement Area*. Some of the information is dated but represents a first attempt to identify and delineate areas of importance.

Traditional knowledge

Local involvement in both research and management has increased considerably. The local and traditional knowledge of northern residents is being systematically collect by interviews and by conducting field research with traditional methods as much as possible. An example is the capture of polar bears using dogs and snowmachines rather than helicopters. The Department of Resources, Wildlife and Economic Development has formed a standing committee on Traditional Knowledge to promote development of cross-cultural initiatives.

Ontario

There have been no changes in the management of polar bears.

The current Polar Bear Management Plan for Ontario recommends that annual aerial surveys be conducted

along the James Bay and Hudson Bay coasts in late-summer to monitor the polar bear population which is onshore at that time. In addition, the management plan recommends that late-winter aerial surveys to monitor cub production by the population of females denning in Ontario be conducted every 5 years and for 2 consecutive years at that time. Annual late-summer surveys were conducted by Wildlife Research Section staff each year from 1993–1996. Late-winter productivity surveys were scheduled to be conducted in 1992 and 1993, but funding was not available. However, funding was obtained and the surveys were conducted by Wildlife Research Section staff in 1994 and 1995. The next late-winter surveys are scheduled for 1999–2000.

Status of local management agreements

An informal meeting was held with local hunters in Peawanuck on 28 August 1996 to discuss several issues around polar bear management. As a follow-up to this informal meeting, initial community information and consultation meetings were held in Peawanuck on 16 September 1996, and in Fort Severn on 17 September 1996. These community meetings were attended by local hunters and Band Council members, by Ontario Ministry of Natural Resources staff from Moosonee, Wildlife Research Section, and Policy Division, and by the Polar Bear Biologist from the Northwest Territories. Topics discussed included results of the 1984–1986 mark-recapture study (Kolenosky *et al.* 1992) with emphasis on population boundaries and movement patterns, sustainable harvest levels and conservation measures, and local management agreements in the Northwest Territories. Community interest focused on issues such as ecotourism potential of polar bears, nuisance bears, and the possibility of sport hunting opportunities for non-Treaty Indians.

At the request of the communities of Fort Severn and Peawanuck, a second round of community consultation meetings was held 14–17 January 1997.

Québec

In accordance with the law on hunting and fishing rights in the James Bay and Northern Québec Agreement, the polar bear harvest is restricted to native people to protect their traditional rights as recognised by the government of Québec. The law makes provision for guaranteed harvest levels that can be taken as long as the principle of conservation is respected. Guaranteed harvest levels were established based on observed polar bear harvest between 1976–1980 and have been agreed to by both Inuit and Cree. The current harvest levels appear to be sustainable and, thus, agree with the principle of conservation.

Following discussions on the ‘Polar Bear Tactical Plan’ with native organizations, it was agreed that the Ministère de l’Environnement et de la Faune (MEF) would not impose additional hunting regulations to those already accepted by native organizations after the negotiation of an agreement on implementing a hunting season (September-May), on the protection of females with cubs, and on the prohibition of the hunting of polar bears in their summer refuge.

A good harvest monitoring program is now in place and the harvest statistics for all the Québec communities over the past 5 years have been recently summarised.

Yukon

There have been no changes in the management of polar bears.

User groups

Inuvialuit Game Council

In January 1988, the Inuvialuit-Inupiat Polar Bear Management Agreement, covering the polar bear population of the Southern Beaufort Sea was signed in Inuvik, NWT and Point Barrow, Alaska. Two committees were set up to ensure annual review of harvest data, research results, and management recommendations: (1) the Joint Commissioners, chosen from the Inuvialuit and Inupiat, and (2) a Technical Committee to be made up of scientists from government agencies and hunters.

At the first Technical Meeting, on 17 October 1988, the total quota was set at 76, to be shared equally by the Inuvialuit and Inupiat. It was also understood by all parties that this level of harvest could only be sustained if the proportion of females in the harvest did not exceed one-third (33.3%). At the meeting on 9 March 1995, in Anchorage, the quota for Inuvialuit settlements was raised by one bear to 39.

Each year, the Technical Committee has been responsible for providing an annual report, on behalf of the Inupiat and Inuvialuit, to account for the way in which the quota was taken and other matters of either interest or concern. The harvest of polar bears in the southern Beaufort Sea for 1988–89 through 1994–95 is given in Table 5. The number of sport hunts, undertaken during the same period, and their success, are given in Table 6.

The Inuvialuit Game Council is concerned with the proportion of female bears in the annual harvest from the Southern Beaufort Sea population. In the last seven years, this proportion has been below the recommended

Table 5. Harvest data for communities hunting polar bears from the Southern Beaufort Sea population in relation to year and sex of bear taken (M = male, F = female, U = sex not reported, X = unused tag). The quota for each community is in parenthesis.

Community	1988–89				1989–90				1990–91				1991–92				1992–93				1993–94				1994–95			
	M	F	U	X	M	F	U	X	M	F	U	X	M	F	U	X	M	F	U	X	M	F	U	X	M	F	U	X
Aklavik (5)	3	1	1	0	0	3	0	2	1	2	0	2	0	0	0	5	2	2	0	1	0	0	0	5	1	0	0	4
Inuvik (1+1) ¹	0	0	0	1	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	2	1	0	0	0	0	2
Tuktoyaktuk (26)	15	5	1	5	15	9	1	1	4	4	1	17	10	14	0	2	13	12	1	0	10	3	0	13	11	8	0	7
Paulatuk (6/17) ²	4	2	0	0	2	2	0	2	1	1	0	4	2	2	0	2	1	0	0	5	0	1	0	5	2	0	0	4
Subtotal by sex	22	8	2	6	17	15	1	5	7	7	1	23	12	17	0	9	17	14	1	6	10	6	1	23	14	8	0	17
Total kill	32				33				15				29				32				17				22			

¹ From 1994–95 onwards, the quota for Inuvik is two.

² An analysis of the origin of tagged bears killed by hunters from Paulatuk indicates that 1/3 of the quota is taken from the Southern Beaufort Sea population each year and 2/3 from the Northern Beaufort Sea population and, thus, the quota of 17 has been allocated arbitrarily, from 1988–89 onwards, to approximate a ratio of 6:11.

³ The total quota kill in 1992–93 includes 1 problem kill from Tuktoyaktuk.

⁴ The total quota kill in 1993–94 includes 1 problem kill and 2 illegal kills from Inuvik.

Table 6. Reported polar bear sport hunts from southern Beaufort Sea communities 1988–89 through 1994–95.

Community	Males	Females	Unknown Sex	Unused Tags	Total
Aklavik	0	0	0	0	0
Inuvik	0	0	0	0	0
Paulatuk	3	0	0	6	9
Tuktoyaktuk	8	4	2	14	28
Total	11	4	2	20	37

level of one-third only once (1988–89). However, since the quota has not been filled in any of these seven years, the total number of females actually taken has remained at a sustainable level. The recommended maximum harvest of females for the first seven years of the agreement was 89 for the Southern Beaufort Sea population while the actual number of females taken totalled only 75. The sex of six bears was not recorded and some of these were probably females. Based on the data for the first seven years, an over-harvest of females has not occurred. However, the fact that the proportion of females in the annual harvest has exceeded one-third in most years is a serious issue that has been recognised and is being addressed by the Inuvialuit Game Council through communication with the Hunters' and Trappers' Committees in each community. A higher-profile educational program is also being initiated in conjunction with the Department of Resources, Wildlife and Economic Development.

Nunavik (northern Québec)

Under the James Bay and northern Québec Agreement (JBNQA) of 1975, the taking of polar bears is restricted to aboriginals to protect the traditional subsistence harvesting rights of northern Québec natives. In law, provisions have been made to ensure the Inuit of Nunavik have exclusive access to an agreed minimum level of harvest (Guaranteed Harvest Level-GHL) subject to the principles of conservation. Set at 62 polar bears per year for the entire region, this level of harvest is based on the recorded subsistence take between 1976–80. While the GHL is not linked to a specific management zone, the greatest numbers of bears are killed in Management Zone SH on the Hudson Bay coast. Although the Government of Québec retains the right to institute conservation measures, this has not been considered necessary to date.

All polar bear skins, including those which Inuit hunters wish to sell, must have a tag attached (issued by Québec MEF). Management resolutions were passed in 1984 by the native hunters' organisation, Anguvigak, to protect (1) females with cubs and (2) bears in dens. These regulations are still followed by Inuit hunters in northern Québec and were ratified by the recently established Nunavik Hunting Fishing and Trapping Association (HFTA), which has assumed the role of Anguvigak.

Under the amendment to the U.S. Marine Mammal Protection Act, polar bears taken by U.S. sport hunters from a population that is shared by more than one jurisdiction could only be brought back into the U.S. if an inter-jurisdictional agreement on the co-operative management of polar bears existed. Since the mid-1980s, the Inuit of Nunavik have expressed an interest in

conducting a guided sport hunt similar to that in the NWT. MEF, who retains management jurisdiction of polar bears in Québec, has specified their support for a sport hunt. However, the area covered by the JBNQA only includes lands under Québec provincial jurisdiction alone, whereas, most polar bear hunting occurs on the sea-ice in the NWT. Although management measures currently exist in Nunavik in context of the harvest of polar bears, it is viewed that co-management agreements involving other jurisdictions would complement such measures due to the trans-boundary nature of the species. In 1995 and 1996, Makivik Corporation and MEF attended two meetings in Iqaluit where the internal NWT co-management agreements were developed and, thus, were able to see the process involved.

In January 1996, a workshop on co-management of wildlife in the marine areas offshore from Nunavik was initiated by the Makivik Corporation. The objectives were to bring Inuit from northern Québec and representatives of both the Federal and NWT governments directly involved in wildlife issues together with negotiation teams to discuss wildlife management in the Nunavik Marine Region (NMR). The premise of the workshop was that co-management of shared populations in the NMR is desirable and that ideas on how that might be achieved should be sought and integrated into the management regimes currently being negotiated by Makivik Corporation, the Federal Government and the Government of the Northwest Territories for the Nunavik offshore area.

Presentations were made showing the results of research conducted on polar bears to date in all three populations. It appeared that the Foxe Basin population had been over-harvested whereas the current levels of harvest of both the Davis Strait and Southern Hudson Bay populations appeared to be sustainable based on data from older studies, satellite tracking, limited recent capture data, and traditional knowledge. The value of an inter-jurisdictional agreement for the management of polar bears from shared populations was recognised and, also, that such an agreement would be non-prejudicial to future settlement of the Nunavik Offshore Claim. Representatives of Makivik Corporation were interested in this proposition and agreed to discuss the idea among themselves at an upcoming wildlife meeting.

At the 1996 PBTC meeting, delegates from Nunavik expressed a willingness to consider establishing quotas for northern Québec polar bears, similar to what has been suggested by the PBTC and previous inter-jurisdictional co-management agreements and, further, that they supported doing population studies to ensure

Table 7. Draft status of Canadian polar bear populations incorporating harvest statistics from 1991–92 to 1995–96 which include all reported human-caused mortalities of polar bears within the NWT, as well as kills reported in Labrador, Québec, Ontario, Manitoba, Alaska, and Greenland. The percent females statistic excludes bears of unknown sex and natural deaths are not included.

Population	Estimate	Reliability ¹	5-year average (91/92–95/96)			3-year average (93/94–95/96)			Current year (95/96)			Population Status ² (5yr/3yr/1yr)
			Kill	% female	Sustainable harvest	Kill	% female	Sustainable harvest	Kill	% female	Sustainable harvest	
SB	1800	good	55.8	36.4	74.2	50.3	30.4	81.0	49	22.5	81.0	+/++
NB	1200	good	29.2	43.0	41.9	22.0	42.4	42.5	15	26.7	54.0	+/++
VM	230	good	1.2	83.3	4.1	0.7	50.0	6.9	0	0.0	10.3	0/++
MC	700	poor	24.6	33.3	31.5	21.7	30.8	31.5	26	26.9	31.5	+/++
GB	900	poor	37.2	42.3	31.9	35.3	46.1	29.3	36	55.5	24.3	0*/0*/0*
LS	1700	good	81.2	24.9	76.5	81.7	26.0	76.5	80	26.9	76.5	0*/0*/0*
NW	100	fair	4.0	30.0	4.5	4.7	42.9	3.5	7	57.1	2.6	0/0/0*
KB	200	good	6.2	37.1	8.1	6.3	38.1	7.9	6	35.0	8.6	0/0/0
BB	2200	fair	122.2	35.4	93.2	120.3	35.0	94.3	117	34.2	96.5	-/-/-
FB	2300	good	117.8	38.4	78.9	104.0	37.5	80.8	95	35.1	86.3	0*/0*/0*
DS	1400	fair	56.9	36.4	57.7	56.3	35.1	59.8	57	36.0	58.3	0/+0
WH	1200	good	43.8	30.9	54.0	43.3	37.5	48.0	36	55.9	32.2	+/+0*
SH	1000	fair	45.4	35.0	41.9	40.3	31.3	45.0	47	35.6	41.2	0*/+/0*
QE	(200?)	none	0.0	—	0.0	0.0	—	0.0	0	—	0.0	0/0/0
Total			625.5		590.2	586.9		598.5	571		595.0	

¹ **good** — minimum capture bias, acceptable precision; **fair** — capture bias, precision uncertain; **poor** — considerable uncertainty, bias and/or few data; **none** — no information available.

² + under harvest; – over harvest; 0 no change, difference of 3 or less between the kill and sustainable harvest; 0* population stable because of management changes.

³ The percent of bears killed that are females is not regulated by law in all populations, but rather percent females is specified as a target in many of the Management Agreements and Memorandums of Understanding. The quota for subsequent years is determined by the number of each sex that are taken the previous year. Quota reductions, sufficient to mitigate an over harvest, are implemented when the sustainable take of males or females, over a five year period, exceeds the sustainable limit.

⁴ Management Agreements or Memorandums of Understanding now exist for all populations in the NWT. These agreements are reviewed periodically as new information becomes available. A small area in the far northeast of the Canadian Arctic Archipelago is not included in the population summaries because harvest activities do not occur there and because inventory studies have not been done.

⁵ Except for the VM population, sustainable harvest is based on the population estimate (N) for the area, estimated rates of birth and death, and the harvest sex ratio (Taylor *et al.* 1987):

$$\text{Sustainable harvest} = \frac{N \bullet 0.015}{\text{Proportion of harvest that were females}}$$

In this equation, the value for proportion of the harvest that was female is the greater of the actual value or 0.33. Unpublished modelling indicates a sex ratio of 2 males to 1 female is sustainable, although the mean age and abundance of males will be reduced at maximum sustainable yield. Harvest data (Lee and Taylor, 1994) indicate that selection of males can be achieved.

⁶ The rate of sustained yield of the VM population is one-sixth that of the other populations because of lower cub and yearling survival and lower recruitment. The projected proportion of the harvest that is female is 15% based on the intention to take only males. A 5-year voluntary moratorium on harvesting bears in the VM population began in 1994/95.

⁷ Communities within the bounds of the FB population have agreed to a phased reduction in quota, such that by 1997 the harvest is the greater of either 91 bears or the sustainable yield, as determined by subsequent population estimates.

⁸ Totals refer to sums of population estimates, including all Canadian jurisdictions and those populations Canada shares with Alaska and Greenland.

that the eventual harvest was established within sustainable limits. This dialogue continues.

Status report on polar bear populations within and shared by Canada

The status of Canada's 14 polar bear populations (Table 7) is determined by the number of individuals in the population, the rates of birth and death of the population, and the rate at which animals are harvested. Additional information relevant to the status of each of Canada's populations are included in the circumpolar summary of polar bear population status.

The population estimate and status of several of the zones were discussed by the PBTC in more detail. The newly-defined Kane Basin (KB) and Norwegian Bay (NW) populations were thought to have only a "fair" reliability to date. The last column in Table 7 indicates the overall trend in the population by showing whether it has been over-harvested, under-harvested or stable in relation to a 5-, 3-, or 1-year time frame.

AEPS case study on the 1973 Polar Bear Agreement

At an Arctic Environmental Protection Strategy (AEPS) meeting in Yellowknife in August 1994, Norway was appointed lead country for a case study of the 1973 Polar Bear Agreement to evaluate how the Agreement has influenced the conservation and management of polar bears and to consider whether the Agreement could serve as a model in resolving similar issues in the Arctic. The Norwegian draft report, *AEPS Task Force*

on Sustainable Development: Case Study on the 1973 Polar Bear Agreement, was reviewed by the members of the PBTC at its 1996 meeting. The PBTC felt that the draft required considerable revision due to errors, inaccurate information, and incomplete sections. In particular, the PBTC was concerned with the unwarranted degree of anti-hunting bias contained within the document. A reply was drafted and forwarded by the Chairman of the PBTC to the Canadian AEPS Task Force.

Canada's National Parks and polar bears

National Parks and National Park Reserves are managed by the Department of Canadian Heritage to maintain the integrity of the ecosystems these parks represent, in accordance with the *National Parks Act* (1988) and *Parks Canada Policy* (1993). Currently, the management of polar bears is a relevant issue in four National Parks (Aulavik and Tuktot Nogait in the NWT, Ivvavik in the Yukon, and Wapusk in Manitoba), two National Park Reserves (Auyuittuq and Ellesmere Island in the NWT), and four National Historic Parks and Sites (Prince of Wales' Fort, Sloop Cove, Cape Merry Battery and York Factory in Manitoba). National Park Reserve is the designation given to a park where unresolved native land claims exist. New parks in the NWT are being considered on Baffin, Bathurst, and Bylot Islands and around Wager Bay. In addition, parts of Southampton Island (NWT) and the Torngat Mountains (Labrador) are being examined for potential inclusion in the National Parks System.

National Parks have an obligation to minimize the risk to visitors from polar bears, while ensuring that

Table 8. Number of permits issued for polar bears, polar bear hides, and polar bear parts to be legally exported from Canada 1 January 1987 to 31 December 1995 (data from Campbell *et al.* 1993 and Canadian Wildlife Service CITES unpublished data).

	1991	1992	1993	1994	1995	Total
Live polar bears ¹	3	1	0	4	6	14
Polar bear hides ²	266	199	261	184	237	1147
Polar bear hides, pieces	4	20	740 ³	2	0	766
Skulls/jaws/teeth	193	21	41	24	29	308
Claws	14	0	10	0	0	24
Feet	0	0	0	1	0	1
Bones	14	2	5	1	1	23
Biological specimens	0	40	333	259	472	1104
Gall bladders	0	0	2	13	0	15
Meat (kg)	36.4	0	0	0	0	36.4

¹ For zoos.

² Includes some hides as head mounts and some as whole mounts.

³ 733 exported for commercial purposes to Denmark.

polar bears and their habitat are not negatively affected by visitor activities. The first arctic parks to be established, Auyuittuq NPR and Ellesmere Island NPR, are located in areas of generally low bear density, and the times of year when the parks are used by visitors and bears do not coincide. However, with the creation of Wapusk National Park and the planned new parks at Wager Bay and north Baffin Island, the timing of visitor and polar bear use of these parks will overlap and will necessitate management actions to avoid conflicts. Currently, visitors to arctic National Parks and National Park Reserves are required to register with park staff which provides an opportunity to discuss polar bears and ways to minimize potential conflicts.

The issue of the possession of a firearm by a visitor, for personal protection, remains unresolved. Only aboriginals exercising traditional rights or park staff involved in wildlife management activities may carry firearms in a National Park. Permits to carry firearms may be granted, on a case-by-case basis, to research parties or expeditions that demonstrate: (1) the requirement of a firearm for protection, (2) that all necessary precautions required to minimize the risk of encountering polar bears will be taken, and (3) competence with, and understanding of, non-lethal deterrents and firearms.

To resolve some of the above concerns, Parks Canada became involved with the PBTC in 1990, to obtain recommendations regarding possible courses of action. A draft polar bear management plan for Auyuittuq and Ellesmere Island National Park Reserves has been written, with the primary aim of minimising bear-human conflicts. This plan has been reviewed by members of the PBTC and has been submitted to local Hunters' and Trappers' Organizations for comment.

Wapusk National Park

A Federal-Provincial Memorandum of Agreement, signed 24 April 1996, established Wapusk National Park in the Hudson Bay Lowlands of northern Manitoba. Wapusk is Cree for white bear. The park boundaries encompass an area of 11,475 km² and protects the majority of the maternity denning area of the Western Hudson Bay polar bear population. Park planning and management issues will be addressed by a management board that will comprise representatives from the Governments of Canada and Manitoba, the Town of Churchill, and the First Nations of Fox Lake and York Factory. A park management plan is to be developed by this board within five years, but, until it is in place, interim management guidelines will provide direction for protecting natural and cultural resources. Existing Aboriginal and Treaty Rights relating to renewable resource use and First Nations land entitlements will be

respected. Concerns have been raised about a potential increase in the number of defence-killed polar bears caused by increased visitation to the park because this would directly impact the available harvest quota for the Western Hudson Bay polar bear population.

Parks Canada recognizes the value of basic ecological research and the value of long-term research within Wapusk National Park. An initial meeting was held in Churchill in August 1996 where Parks Canada staff and researchers from a variety of disciplines met to discuss mutual concerns about ongoing and future research and research priorities required to address management issues within the new park.

Federal Government

CITES

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973) (CITES) has been in effect since July 1975. Polar bears are included in Appendix II to the Convention ('all species which although not necessarily now threatened with extinction, may become so unless trade in specimens of such species is subject to strict regulation to avoid utilisation incompatible with their survival').

Since July 1975, a permanent record of all polar bears, hides, or any other products legally exported from or imported to Canada has been maintained by the Federal Government through the issue of permits. Data for 1975–1990 were included in the management reports prepared for the previous four IUCN Working Meetings. The 1991 through 1995 data are summarised in Table 8.

National Accord for the Protection of Species at Risk and Endangered Species Legislation

On 2 October 1996, federal, provincial, and territorial ministers responsible for wildlife agreed upon a *National Accord for the Protection of Species at Risk* whereby their respective governments will co-operate to ensure that complimentary legislation and programs are put in place to protect endangered species across Canada. On 31 October 1996, the *Canada Endangered Species Protection Act, Bill C-65* was tabled in the House of Commons of Canada. The Act is the federal cornerstone of the National Accord and is intended to prevent Canadian wildlife species from becoming extirpated or extinct and to provide for the recovery of those that are extirpated, endangered or threatened as a result of human activity. It will apply to Canadian indigenous species, sub-species, and geographically distinct populations of wildlife at risk that occur: (1) in either of

Canada's two territories, (2) in the oceans out to the 200 mile limit, and (3) on all federal lands including national parks and all other property managed and administered by the federal government. Wildlife at risk means an extirpated, endangered, threatened or vulnerable species and will be determined by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) based on the best available scientific and traditional ecological information.

When a species is listed as either endangered or threatened, the Act provides prohibitions against activities that harm individuals of the species, authorises prohibiting activities that harm species that cross Canada's international boundaries, and prohibits activities that cause damage or destruction to habitat that is critical to the survival of the species. The Act also contains provisions enabling emergency action, including habitat protection, when circumstances warrant.

The Act respects Aboriginal and treaty rights and the authority of other federal ministers and provincial governments. These provisions do not apply to persons who are engaging in: (1) activities authorised by or under any other Act of Parliament for the protection of national security, safety or health (including plant and animal health); (2) activities in accordance with regulatory or conservation measures for wildlife species under an aboriginal treaty, land claims agreement, self-government agreement or co-management agreement that deals with wildlife species; or (3) activities authorised by a responsible minister by an agreement, permit, licence, order or similar document.

The Act has only had first reading in the House of Commons. The Act, or any of its provisions, comes into force on a day or days to be fixed by order of the Governor in Council. However, as polar bears are currently listed as vulnerable by COSEWIC, prohibitions provided for under the Act would not apply. A revised status report on polar bears is currently being written for COSEWIC and it is expected that polar bears will again be classified as vulnerable.

Amendment of the US Marine Mammal Protection Act

In April 1994, the US Marine Mammal Protection Act (MMPA) was amended to allow for the importation into the US of polar bear hides taken in sport hunts in Canada. One of the requirements of the Amendment is that the taking of polar bears does not contribute to an over-harvest of the population from which the animals came. Thus, the US Fish and Wildlife Service had a number of queries concerning polar bear management in Canada. In addition to detailed information provided

by the NWT Department of Renewable Resources and the Canadian Wildlife Service, representatives of the US Fish and Wildlife Service were invited to attend the PBTC meetings to gain an overall perspective on the research and management of polar bears in Canada.

Separate workshops were held immediately after the 1995 and 1996 PBTC meetings to specifically review Canadian polar bear populations with respect to the amendment to the MMPA. This timing allowed for data provided at the PBTC meeting to be reviewed and clarified if necessary. Additional information could be requested if required. In addition, it allowed for all jurisdictions present at the PBTC to be represented if they wished.

It was clearly noted that the purpose of the workshops was not to question Canada's management or sport hunting programs but rather to gather as much additional background information as possible for use by the US Fish and Wildlife Service should they be queried about their recommendations.

At the 1997 meeting of the Federal-Provincial Polar Bear Technical Committee, the guided non-resident sport hunt was raised. After discussion, the PBTC unanimously agreed upon the following statement: "The harvest of polar bears in Canada is based upon research on population size and demographic parameters, and is controlled by the establishment of sustainable annual quotas for each sub-population. For sub-populations where indigenous hunters guide non-resident sport hunters, bears taken on such hunts are not additive to, but rather comprise part of, the total allocated quota. Because not all sport hunts are successful, and tags allocated cannot be used by anyone else, a consequence of the sport hunt is that fewer bears are taken than if there was no sport hunt. A second beneficial consequence of the sport hunt, from a conservation perspective, is that a higher proportion of the bears taken are males than in the subsistence hunt and thereby provides an additional measure of protection to adult females. For these reasons, in the view of the Polar Bear Technical Committee, the fraction of a sustainable quota that is used for sport hunting is not a conservation issue."

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Appendix 1

Flexible quota (sex ratio) option developed for sustainable sex-selective harvesting of polar bears in the Northwest Territories

Background

The sustainable yield of polar bears is affected by 3 factors: rates of birth and death, numbers of bears, and sex ratio of the harvest. Managers and hunters cannot affect the first two factors, but hunters can limit the harvest of females. If hunters limit the harvest of females, sustainable quotas can be higher; but the number of males will decline and stabilise at lower levels, and the males will be younger. We recommend that the harvest ratio not exceed 2 males for every female. A 2 males:1 female harvest ratio yields a population that has 30% fewer males with the mean age of males reduced from 10 to 8 years. However, a selective harvest quota can be 50% higher than an unselective one (1:1 sex ratio).

In recognition of the hunting skills of local hunters, Local Management Agreements have been based on the intention to limit the female kill by prescribing a harvest sex ratio of 1 female:2 males. In some areas this has been left as a target, and in other areas this has been established as a regulation. The regulation sets the number of tags that are “either sex” and leaves the others as “male only”. Both approaches have had some difficulty to implement.

In some areas where the sex ratio has been left as a target, the kill of females has exceeded the sustainable yield in some years. For other communities where the sex ratio has been set in law, some hunters have had difficulty in discriminating between males and females. This has led to honest mistakes. Attempts to accommodate the errors administratively have led to inconsistent law enforcement and confrontations in some areas.

Procedures

A “Flexible Quota Option” has been developed to simplify administration of the polar bear quota by using a one-tag system. This will allow for mistakes in sex identification, allow for community preferences in sex-selective hunting, yet keep the harvest within sustainable yield. It is based on the number of male and female bears that can be taken annually.

The population quota based on unselective harvesting is first divided between the communities that harvest polar bears from it. In the first year this baseline quota is increased based on the assumption that the

community would prefer the maximum quota and will harvest 2 or more males per female and remain within the quota. The quota for the next and subsequent years is determined by the harvest history.

The flexible quota system has two parts. The first is a harvest tracking system that monitors the number of females and males killed in the past. Our implementation of the flexible quota system looks back 5 years to see if the full sustainable yield of males and females has been taken. If the sustained yield has not been taken, there are “credits” that may be used to mitigate an over-harvest in the last harvest year. If the full sustained yield has been taken, then the impact of over-harvest must be mitigated by quota reductions in future years. Our implementation of the flexible quota system does not allow an over-harvest deficit to build. The quota reduction made the following year completely compensates for any over-harvest of females or males. Provided there is no over-harvest in the reduced quota year, the quota may return to the former (maximum) number.

It is useful to explain the flexible quota system in two parts. To make it simple, assume there are no “credits” or “penalties” for males or females in the past. We start clean and base the initial quota on the assumption that the harvest will be 2 or more males per female. If the kill of females is not more than their sustainable yield, and the sex ratio of the harvest is less than 1 female bear for every 2 males (say, 26% females and 74% males), the quota for the following year will still be at its maximum. The maximum quota is calculated as the sustainable yield of females plus twice that number for males. There will be no correction for what seems like an over-harvest of male bears because those females not harvested will reproduce and make up the difference in the additional number of male bears taken. If the kill of females is exactly the sustainable yield, and the kill of males is exactly the sustainable yield, then sex ratio of the harvest must be 1 female for every 2 males. Again, the quota for the following year will be at its maximum.

Reductions to the quota occur only when there is an over-harvest of males, and the maximum number of females is taken or exceeded. For the male over-harvest, the correction is easy, it is only one tag for each male over-harvested. However, when females are over-harvested, two things have happened. The first is that the number of females that can be taken has been

exceeded. The second is that the community has indicated that they cannot or choose not to harvest at 2 males per female. The second information is critical in determining the correct response to the over-harvest, because it determines how many tags must be withheld to reduce the female kill by one. If the overkill of females is greater than the sustainable yield of females in a given year, there will be no quota for the following year. Subsequent year quotas will be reduced to accommodate any remaining overkill not covered.

The above procedures can be summarised as follows. The number of quota tags allocated depend on the community allocation of the sustainable yield of females (F) for a given population, the actual number of females killed in the previous year (K_{t-1}), and the proportion females in the total harvest in the previous year (P_{t-1}). The quota for the current year (Q_t) is defined as:

$$Q_t = \frac{2F - K_{t-1}}{P_{t-1}}.$$

The value of $(2F - K_{t-1})$ cannot exceed F, and the value of P_{t-1} cannot exceed 0.33. If the value of $(2F - K_{t-1})$ is less than zero, the quota is zero; and K_t is assigned the value $-(2F - K_{t-1})$ for calculation of the subsequent year's quota. The sex ratio from one year's harvest provides an indication of the expected sex ratio for the next year. In the long term, the kill will not exceed the sustainable yield of females because the quota is reduced in the following year (or years if necessary) if an overkill of females occurs. The kill will never exceed the sustainable yield of males because the maximum possible quota is based on the recommended sex ratio (1 female for every 2 males).

The purpose of this system is to provide a "self-directed" quota system that keeps the kill within sustained yield, but allows each community the flexibility to harvest polar bears in a manner that suits their needs. However, this system must be implemented in a manner that does not unnecessarily reduce polar bear harvest opportunities. For example, in some areas harvest opportunities are greatly reduced in some years by bad ice which restricts travel. In those years almost no polar bears are taken. Given the under-harvest in the example, it would be inappropriate to reduce a quota based on the next years harvest that was perhaps a female over. The implementation of the flexible quota system examines the past 5 years of harvest history for the community and the population. If a community has "credits" to address an over-harvest in a particular year, these are automatically implemented. If a community has exhausted their "credits" and another community in the same population has "credits" and gives permission, "credits" may be exchanged within a population. Quota reductions are only implemented when required, and the reduction is temporary. If males and females are not over-harvested, the quota can return the following year to the maximum level set by the sex-ratio up to 2 males per female.

This quota system will be adopted into regulations which will allow the quota to vary by community and year, accommodate differences in hunting preferences, keep each population within sustainable yield, and allow a single tag (unisex) system for sealing the hides. The flexible quota system would allow all tags to be used in a given year regardless of the sex of the bears harvested.

Research on Polar Bears in Canada 1993–1996

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Most polar bear research in Canada is conducted by Federal, Territorial, and Provincial governments. Primarily because of the cost involved, but also because of the management responsibilities of those various governments, co-operative research is often undertaken where the project is of interest to several jurisdictions. Some research projects conducted by university researchers are co-ordinated with government research through bilateral discussions and through the Federal-Provincial Polar Bear Technical Committee (PBTC). Other projects are supported with funds from Wildlife Management Boards established by the land claims process, by independent foundations, and through grants to students co-supervised by Government and University researchers. This report summarises the research conducted, organised by lead agency, and lists publications and reports completed, between 1993 and 1996.

Canadian Wildlife Service (CWS)

Polar bears and the arctic marine ecosystem

Priorities for research in the Federal Department of Environment are aimed at increased understanding and conservation of ecosystems. This is, in part, due to Canadian commitments under the Biodiversity Treaty and Canada's broad commitment to the protection of polar bear habitat under the International Polar Bear Agreement. To this end, the CWS Polar Bear Project has been renamed Marine Science and is expected to take an ecosystem perspective. The direction that CWS

research is expected to take in the next few years is exemplified by two current overview projects: variability in natality of polar bears in relation to fluctuations in arctic marine ecosystems (Stirling and Lunn 1997), and relationships between distribution and abundance of bears and seals. The first stage of the latter project was done in collaboration with Nils Øritsland at the Norwegian Polar Institute in Oslo (Stirling and Øritsland 1995).

Behaviour of polar bears and interrelationships with seals

In June-July 1996, CWS reactivated studies of the behaviour of free-ranging polar bears in the High Arctic at Radstock Bay, Devon Island, NWT. Observations of individual bears summed to 446 h. Four kills of ringed seals were observed. Habitat types in the bay, and those most used by the bears or the seals, were recorded. Regular counts of hauled-out seals were made. Observations from the research camp are planned for the 1997 and possibly the 1998 spring and summer seasons. Data will be analysed in conjunction with similar data collected in previous years.

Western coast of Hudson Bay

Studies of the polar bear population on the western coast of Hudson Bay have continued. From 1993 through 1996, there were five components to the CWS research: monitor the condition of bears of all sex and age classes,

the reproductive rates of adult females, and the survival of their cubs; assess the size and boundaries of the population; evaluate terrestrial habitat selection by polar bears spending the ice-free period on land; evaluate the antiquity of earth denning in the Churchill denning area; and, beginning in the fall of 1996, study habitat and den-site selection of pregnant adult females. Data for these studies were collected concurrently, but the study designs are treated separately in the sections following.

Condition, reproduction, and survival of polar bears on the western coast of Hudson Bay

Long-term studies of polar bears on the western coast of Hudson Bay revealed that both the condition and the survival of cubs had declined over the last 15–20 years. It was important to monitor this population to determine if the decline was a natural variation, and thus not a matter of concern, or was signalling matters of greater ecological significance in the marine ecosystem of Hudson Bay.

To address this question, CWS has continued to capture a sample of bears each spring and again in the fall so bears of all age and sex classes can be weighed and an index of their condition assessed. Conventional radio collars on adult female bears leaving maternity dens in the spring aid fall recapture to determine the survival rate of their cubs. Satellite radios on female polar bears are used to determine winter and spring movements on the sea ice and to determine what types of habitat are used when the bears fast on shore through the late summer and fall. At a later date, movements of these female bears in relation to ice conditions will also be examined.

In addition to collecting data for the population monitoring studies, specimens and data for other studies were also collected. Blood specimens were collected for the US Fish and Wildlife Service in Anchorage, as part of a circumpolar survey of viral antibodies. Fat specimens were collected as part of a long-term program in conjunction with the Canadian Wildlife Service in Ottawa, in which toxic chemical levels in individual polar bears are being monitored through time (see section on Toxic Chemical Analyses).

In the fall of 1993, 150 polar bears were captured and measured, 15 adult female bears carrying conventional radio collars were resighted or recaptured, and 12 satellite collars were removed. The survival of cubs during the 6 months from the time of their handling or sighting in the spring to their handling or sighting in the fall was 52% (16/31), which was similar to the previous several years.

In spring 1994, 100 polar bears were handled, including 33 females with cubs of the year (COYs). Sixteen conventional VHF collars were deployed and one satellite collar removed after being carried by a female for the past two years.

Beginning in spring 1994, the capture effort was extended inland south of Cape Tatnam and east of the Nelson and Hayes rivers, to determine the importance of this area for maternity denning. Seven family groups were handled: all were within 50 km of the coast (five within 30 km) and appeared to have travelled for several days. Their tracks were followed further inland, but no dens were found, as wind had erased all but the most recent tracks. Two satellite collars were deployed.

In fall 1994, 170 bears were captured. One satellite collar was deployed in the Cape Tatnam area on an adult female with two COYs. In the region between the Nelson River and the Ontario border, all adult females with cubs encountered in September were near the coast. This contrasts markedly with the area between the Churchill and Nelson rivers, where females and cubs tend to spend the summer 50–80 km inland in the maternity denning area. This may suggest that (1) Cape Tatnam is not a major denning area, (2) den sites occur at very low density, (3) the denning area is further inland than the area surveyed, or (4) females with cubs prefer to spend the onshore period along the coast in that area. None of these hypotheses is mutually exclusive.

In spring 1995, a total of 64 polar bears were handled in the Churchill denning area, including 22 females with COYs. The Ontario Ministry of Natural Resources (OMNR) flew a series of three polar bear surveys at two-week intervals that covered coastal and inland areas of Manitoba as far west as Cape Tatnam. The CWS work in the area south of Cape Tatnam and east of the Nelson and Hayes rivers was planned to take advantage of the information gained on these survey flights. On the first OMNR survey (26 Feb) only 2 single bears were seen. CWS worked in the area during the second survey (8–9 Mar), deploying 1 satellite collar on a female with 3 COYs and handling a solitary female. No other bears were seen and fewer than half a dozen tracks were recorded in the area by either CWS or OMNR. CWS returned to the area on 16 March and, despite nearly ideal conditions and flying more than 640 km, saw neither bears nor fresh tracks.

In fall 1995, 177 bears were captured. In the region between the Nelson River and the Ontario border, most (5 of 7) adult females with cubs were encountered near the coast. This pattern was similar to fall 1994 in the same area but contrasted again with the area between the Churchill and Nelson Rivers where most females

and cubs spend the summer in the inland denning area. Two females with cubs were located inland by radio telemetry: one was 27 km from the coast and the other 40 km. Two satellite collars were deployed between Cape Tatnam and the Manitoba-Ontario border: one on a female with two COYs and the other on a female with two yearlings. In addition, a satellite transmitter was removed from a female collared in September 1994. Five adult females captured between the Nelson River and the Manitoba-Ontario border were carrying satellite transmitters in fall 1995.

In spring 1996, 14 adult females were captured and 12 conventional VHF collars were deployed on adult females in the Churchill denning area.

Population assessment of polar bears in western Hudson Bay

Both mark-recapture and telemetry studies indicate that the Western Hudson Bay population of polar bears is located in an area bounded by Rankin Inlet in the north and the Manitoba-Ontario border in the south. Based on mark-recapture studies conducted between the Churchill and Nelson Rivers, this population was estimated at 1,000 animals in 1992 but relied on the assumption that all bears were randomly mixed. However, recent data suggested that polar bears showed some degree of geographic fidelity to summering areas and there had been reports of additional maternity denning south of the Nelson River, in the vicinity of Cape Tatnam. Due to these considerations, it was felt that the 1992 population estimate might be low. Therefore, for management purposes, the population was assumed to be 1,200 animals.

In 1994 and 1995, funds were allocated by the Nunavut Wildlife Management Board to help fund a two-year study with the following objectives: (1) to ensure adequate sampling of the population between the Nelson River and the Manitoba-Ontario border to allow the size of the population to be estimated to provide the basis for reviewing quotas, and (2) to deploy satellite collars on adult female bears captured between the Nelson River and the Manitoba-Ontario border to determine the movements of these bears during spring and winter as an aid in finalizing the southern boundary of this population.

Jolly-Seber models were used to estimate the size of the population from three datasets: bears handled in the main Churchill Study Area (CSA) between Churchill and the Nelson River from 1979–1995; bears handled in the same area but from 1984–1995; and bears handled between Churchill and the Manitoba-Ontario border (CMOB) from 1984–1995. The last data set incorporated mark-recapture data collected by the Ontario

Ministry of Natural Resources along the Ontario and eastern Manitoba coasts from 1984–1986. All three data sets gave similar estimates of the Western Hudson Bay population in 1995 of 1,250–1,300 polar bears. However, because no mark-recapture studies were conducted south of the Nelson River from 1987 through 1993, there was concern that a possible confounding influence from the 1987–1993 capture effort may have had a disproportionate effect on the estimates. Thus a population estimate independent of these effects was obtained by applying a Lincoln-Petersen model to data collected between Churchill and the Manitoba-Ontario border in 1994 and 1995. This model estimated the population in 1995 to be $1,249 \pm 274$ animals, which was similar to the three Jolly-Seber estimates. Thus, our best estimate of the Western Hudson Bay polar bear population is $1,250-1,300 \pm 200$ animals. From a management perspective, it is probably prudent to continue to manage the population on an estimated 1,200 polar bears.

Data from both the movement and mark-recapture studies suggested that the current boundary between the Western Hudson Bay and Southern Hudson Bay populations is correctly located.

Habitat and den-site selection by polar bears in western Hudson Bay

When Hudson Bay becomes ice-free from mid July to early August, polar bears resident in western Hudson Bay are forced ashore. They segregate on shore until mid November when they move back onto the sea ice. Adult males normally remain along the coast whereas pregnant females and adult females accompanied by cubs generally move inland into the denning area. While inland, pregnant females tend to occupy earth dens dug into peat banks in areas of discontinuous permafrost. Although bears of other age and sex classes have also been observed in earth dens, they do so to a much lesser degree. Initially, the use of earth dens was thought to be a means to avoid the summer heat, insect harassment, and potential threats from other bears, and possibly for a limited amount of maternity denning. However, it now appears that most polar bear cubs in western Hudson Bay are born between mid November and mid December. Thus, most births occur prior to the accumulation of the amount of snow required for the construction of snow dens. Therefore, most females probably give birth in earth dens. Consequently, the availability and use of earth dens could be critical to the reproduction and survival of the Western Hudson Bay polar bear population.

In the summer of 1996, a four-year project was initiated to increase our understanding of the selection and

use of earth dens because of their importance to the conservation of polar bears in western Hudson Bay. In particular, the research will focus on the use of satellite technology to study the selection of denning habitat by pregnant females, their behaviour around dens during late summer and fall, whether they remain throughout the winter in the same dens they used in the summer, and their time of emergence in spring. This technology will allow for the collection of data, over a two-year period, on both the location and activity levels of individuals with minimal disturbance apart from the initial capture to attach the satellite collar. To minimize the effect of handling on subsequent den selection by pregnant females, collars will only be deployed on adult females accompanied by yearlings because these bears will return to the sea ice in the fall, wean their cubs the following spring, mate, and be pregnant when they next come ashore. Therefore, one year will have passed between our handling of a bear and its selection of a den site.

Ten satellite collars were deployed on adult females accompanied by yearling cubs in fall 1996 and their movements and activity levels continue to be monitored. An additional 8 satellite collars will be deployed in the summer of 1997. The project will be completed in the fall of 1999.

Distribution and abundance of ringed and bearded seals in western Hudson Bay

In early June 1994 and 1995, medium altitude, systematic, strip-transect aerial surveys of ringed and bearded seals were flown in western Hudson Bay to gain quantitative information on the distribution and abundance of seals to: (1) examine possible relationships between the population of seals and the population of polar bears resident in the same area, which has shown marked changes in reproductive parameters over the past 15–20 years; and (2) provide a quantitative database for seals in western Hudson Bay that could be used as a reference point against which future surveys could be compared to determine if changes in the distribution or abundance of seals are taking place. The survey was repeated in 1996 and is planned to be done for 4–5 more years.

Transects were oriented east-west and spaced at intervals of 15' of latitude with the shoreline of Hudson Bay and 89° 00' W longitude being used as the western and eastern endpoints of each transect, respectively. Several findings from the surveys flown in 1994 and 1995 resulted in modification in the design of the survey: (1) the area north of Arviat was largely open water during the time most suitable for conducting the survey; and (2) ringed seals preferred consolidated pack ice, which was most extensive in the region between

Churchill and Arviat. Therefore, with respect to monitoring changes in the distribution and abundance of seals, it was considered most cost-effective to fly only those survey transects that were between Churchill and Arviat.

Mean density of ringed seals hauled out on the ice was four times higher in 1995 than in 1994 (1995, $\bar{x} = 1.690$; 1994, $\bar{x} = 0.380$). The 1994 survey appeared to underestimate seal abundance because it was flown too late. Ringed seals preferred high ice cover habitat (6+/8 ice) and, within this habitat, favoured cracking ice and large floes. No consistent effect of either wind or cloud cover on habitat preference was detected. An estimated total of 1980 bearded seals and 140 880 ringed seals were hauled out on the sea ice in June 1995. The Stirling and Øritsland modelling of the relationship between ringed seal and polar bear populations suggests that a visible population of this size should support a population of up to 1300 polar bears, which is in general agreement with the current estimate of 1250–1300 bears in western Hudson Bay.

Terrestrial habitat use by polar bears

Doug Clark completed an M.Sc. study at the University of Alberta on terrestrial habitat use by polar bears. The abstract follows:

Polar bears in western Hudson Bay are forced ashore from late July to early November each year by melting sea ice. During this ice-free period, bears segregate by age and sex. Investigations were conducted on habitat selection by different age and sex classes of bears during the ice-free period using both capture data from 1966 to 1994 and relocations from PTT collared adult females in 1991 and 1992. Capture and telemetry locations were compared with habitat types classified from scanned LANDSAT TM images, and habitat descriptions noted at capture locations. Factors that might affect habitat preferences were examined including berry production, avoidance of conspecifics, and denning opportunities. Avoidance on adult males and the distribution of suitable denning habitat appear to influence habitat selection by female bears, whereas berry production does not. Subadult bears do not appear to select different habitat types than those used by other bears.

Polar bears in the Hudson Bay Lowlands dig different types of structures in permafrost, which they use throughout the on-shore season. Dens consist of entrance tunnels with an inner chamber, and resemble maternity dens dug in snow by polar bears. Shallow pits seem to be temporary resting places, and the function of shallow dens, or pit-dens, is unclear. Pits and pit-dens

are primarily occupied by lone, presumably pregnant females, while pits are generally occupied by adult males and used more during summer than autumn. These structures each play a role in thermoregulation.

Study of age and long-term use of earth dens by polar bears on the western Hudson Bay coast

From 1994 through 1996, Peter Scott conducted post-doctoral research with I. Stirling at the University of Alberta on relationships between den history and stresses in trees at den sites.

The Western Hudson Bay population of polar bears is uniquely dependent on the use of peat dens. The bears reside in these dens during the summer fasting period and possibly use them as maternity dens in early winter before sufficient snow has accumulated to enable construction of snow dens. The objectives of the study of peat dens have been twofold: to examine what is characteristic about the region that makes it suitable for denning, and to determine the antiquity and history of use of the dens.

Examination of den sites revealed that the dens were situated along embankments and beneath root matrices formed by black spruce krummholz. Cross-sections of trees at den sites were sampled for examination of physical damage, stem shifting, and other disturbances that could indicate years of den construction, occupancy, and collapse. The oldest trees sampled to date are exceed 350 years and strong evidence for the presence of bear dens has been dated to nearly 200 years ago. Other dates are more tentative, partly because of the uncertainty of attributing the tree damage to polar bears and partly because the dens cannot always be identified with certainty because of ground slump and vegetation establishment over many decades. This study will enable us to accumulate knowledge of where and when dens were built, how frequently they have been used, and how long a den might last. The study began in 1993 and each year additional dens have been investigated. The collective information may be used to derive information about the size and importance of this denning area for a period of over a century or more.

In conjunction with determining the insulative capacity of the peat, temperatures are being recorded at approximately 1 hour intervals by remote micro-loggers that are connected to thermistors installed in the roof of a sample of bear dens. Outside the dens, site temperatures are being recorded for comparison using a similar method. Ten dens have been instrumented including one den that was occupied at the time of instrumentation. The temperature profiles will indicate the thermal

characteristics during all seasons and den use will be indicated by temperature changes as well.

Northeastern Beaufort Sea (with Inuvialuit Game Council)

A study of the polar bear population in the northeastern Beaufort Sea was undertaken during April and May of 1992–1994. The main objective was to determine the pattern of seasonal movements of adult females in the mouth of M'Clure Strait and along the west coast of Prince Patrick Island to determine the boundary between the Northern Beaufort Sea and Viscount Melville Sound populations. Additional objectives were to capture a sample of bears to determine the proportion of bears tagged further south in the Beaufort Sea during studies conducted in the 1970s and mid 1980s and, if possible, estimate the numbers of bears resident in the northeastern Beaufort Sea. It was not possible to get a reliable estimate of numbers of bears because polar bears occur in low densities and thus it was not possible to capture enough animals in any year. Mean weights of adult males, adult females accompanied by COYs, and adult females without COYs were lower than those for comparable groups of bears captured in the southeastern Beaufort Sea, Amundsen Gulf, and along the west coast of Banks Island. Subadults and young adults were noticeably absent in the capture samples. In general, the northeastern Beaufort Sea was dominated by multi-year ice, habitat less favoured by ringed seals, the major prey of polar bears.

Movement data and the proportion of tagged animals in the capture samples both suggest that there is little mixing of bears from the west coast of Banks Island with those further north in M'Clure Strait and along the west coast of Prince Patrick Island. Adult females tended to show a high degree of fidelity to the area. None moved eastward through M'Clure Strait into Viscount Melville Sound, suggesting that the correlate boundary between the two populations is correct. The final report has been completed (Lunn *et al.* 1995).

Polar bear movements in the Labrador Sea (with Labrador Inuit Association)

In the late 1970s, a preliminary mark and recapture study was conducted by CWS on polar bears along the northern Labrador coast in late winter and early spring. During that period, six bears tagged on the Labrador coast were recaptured in the same area in subsequent springs, indicating there was some seasonal fidelity in their annual movements. Two bears were recorded moving between the northern Labrador coast and southeastern Baffin Island, as was expected, one of which was subsequently recaptured back in Labrador.

However, two bears also moved between northern Labrador and northern Hudson Bay. One polar bear tagged in Labrador was shot at Seahorse Point on Southampton Island and a second bear, tagged on Mansel Island in northern Hudson Bay, was recaptured in Labrador. From these preliminary results, it appeared that most bears found along the Labrador coast in late winter and spring migrated there from Baffin Island but some came from as far away as northern Hudson Bay. The sample sizes were too small to draw firm conclusions about what proportion of the bear population along the Labrador coast originated from each area. The mark and recapture data suggested there were 60–90 bears along the northern Labrador coast in spring. No evidence of maternity denning was reported during the 1970s.

In more recent years, the PBTC expressed concern about the number of bears being harvested annually from northern Hudson Bay, Foxe Basin, and Hudson Strait by Inuit from the Northwest Territories and northern Québec. Because of the limited amount of movement data available, it was not clear what proportion of the legally harvested and problem polar bears killed along the Labrador coast might be coming from northern Hudson Bay and Foxe Basin in relation to those originating from the shared population distributed in southern Davis Strait, southeastern Baffin Island, and the Labrador Sea.

From 1991–1994, the Labrador Inuit Association (LIA) and CWS captured polar bears and deployed satellite collars along the northern Labrador coast and in the Labrador Sea. William Barbour, from the LIA, participated in all four years of field work. The objectives of this co-operative study were as follows:

1. To place satellite radios on adult female polar bears to determine their distribution and pattern of movements;
2. To tag a sample of polar bears to obtain a crude open population estimate of the number of polar bears present along the Labrador coast in late winter and early spring;
3. To determine where female polar bears found on the Labrador coast have their maternity dens and cubs;
4. To summarise current and living memory knowledge of polar bears from local people for incorporation into this report; and,
5. To compare data from this study with those collected in the 1970s for any indication of population trends.

During the study, 1991 through 1994, 64 bears were caught (12, 22, 16, and 14 in separate subsequent years).

There were 24 adult males, 18 lone adult females, 3 females with cubs, 9 subadult males, and 7 subadult females.

Most radio-collared bears moved north to the southeastern coast of Baffin Island although two travelled to Foxe Basin and northern Hudson Bay before moving east to Hudson Strait and Hall Peninsula. Three bears appear to have had maternity dens on Hall Peninsula, though none has been re-sighted with cubs to confirm this.

Two bears collared in the spring of 1993 were still in Labrador in late December. One was caught with cubs in spring 1994, thus confirming maternity denning on the Labrador coast for the first time in many years.

Anecdotal observations of possible maternity dens and a family group have been reported. On 12 October, 1991, and 3 November, 1992, polar bears were found in snow dens near Cape Territok and Saglarsuk Bay that may have been maternity dens if the bears were females. In late May, 1991, a videotape of a female polar bear with COYs was made approximately 10 km north of Hebron by personnel from the North Warning Station at Saglek. The location of their maternity den was unknown but, because of the small size of the cubs and the time of the year, it likely was on the Labrador coast. Maps prepared by Brice-Bennett in 1977 recorded the areas where Labrador Inuit reported maternity denning of polar bears in the past. However, no indication was given of the type or extent of the information on which her maps were based.

Although the available information suggests there is little maternity denning of polar bears along the Labrador coast, two factors may negatively bias the chance of denning being recorded, especially in recent years. Since the closing of settlements such as Port Burwell and Hebron, few people now travel along the Labrador coast north of Nain in the early spring. The Labrador coast is quite far south in polar bear range so it is possible that female polar bears leave their maternity dens by early to mid March, as they do on the western coast of Hudson Bay. This might serve to shorten the time in which anyone flying along the coast might make casual sightings.

In 1994, a unique opportunity became available to capture and mark polar bears in the southern extremity of the range of the population in the Labrador Sea-Davis Strait. The Canadian Department of Fisheries and Oceans chartered an icebreaker for the month of March as part of their project to re-estimate the size of the harp seal population in the Labrador Sea. I. Stirling was invited to work off an icebreaker in the Labrador Sea

and help with the seal work and to capture polar bears opportunistically as a continuation of the LIA-CWS study of the Davis Strait-Labrador population.

Six eartag radios were deployed on adult males in the general area of the harp seal patch, and one Telonics satellite collar was put on a female. All the bears moved northward through the pack over the next month or two, then all the eartag radios ceased functioning. Three eartag radios were also put out on males captured along the northern Labrador coast. Two of the eartag radios, both without their antenna, were recovered from bears shot by Inuk hunters, one in northern Québec and one on SE Baffin Island. Both were tested and found to be working normally.

It is also hoped that a survey of living-memory information on polar bear denning, movements, and natural history from Inuk elders in Labrador will be included in the final report. Harvest information and miscellaneous sightings of polar bears in Newfoundland will be included. From these sources, some insight into the perception of polar bear natural history may be obtained from residents. This may be helpful in interpreting results and, eventually, in making recommendations.

National polar bear data base

The data base continues to be maintained on desk-top personal computers, though networking facilities are being used to permit more than one workstation to access the complete data set. In addition, stand-alone subsets of data are being used on laptop computers in field camps for record-checking and data entry. Advanced Revelation is the software package used and developed by CWS for the master database in Edmonton. Since 1995, NWT have also used Advanced Revelation for data entry and extractions, in order to use the software applications that have been designed for the polar bear records.

Currently, the database contains 33,000 separate records of polar bear occurrences, including bears sighted and handled during mark-recapture programs, and all bears recorded as killed or found dead. Some modifications to the entry and edit windows and programs were developed in late 1996 and early 1997. This will accommodate the increased scope and complexity of the database. Protocols were also designed to ease the exchange of data from various jurisdictions, and to control the edit procedures. The intention is to maintain sufficient flexibility in data export that reports and data sets can be exchanged with jurisdictions using different database or analysis software.

A workshop was held in Edmonton in January 1997 to review field definitions and collection sheet standards, resolve conflicts in data entry and management, and establish protocols for exchange of data.

Studies on toxic chemicals in polar bears (with NWT, University of Saskatchewan)

Polar bears were sampled in 1989–1993 through most of the range of the polar bear from Wrangel Island in Russia eastward to Svalbard for determination of chlorinated hydrocarbon contaminants (CHCs). Over 700 rump fat samples taken by hunters and rump fat biopsies collected by polar bear biologists were analysed for PCBs, DDE, Chlordanes and dieldrin. PCBs and Chlordanes were the major CHC residues accumulating in polar bears. Statistical analysis indicated that there were limited effects of age after age 5 but there were differences between sexes in PCB and Chlordane concentrations. For comparison among areas, the data for bears age 5 were grouped according to the best estimate of sub-populations, and standardized to males based on the SAS GLM model (Norstrom *et al.* 1997). The lowest concentrations of all four CHCs were generally found in Alaska and the central Canadian Archipelago. The highest concentrations of PCBs were found in Svalbard, East Greenland and in the Arctic Ocean near Prince Patrick Island in Canada. These were significantly higher ($p < 0.05$) than the lowest areas, such as Alaska. Chlordane, DDE and dieldrin concentrations were more even distributed than PCBs, but tended to be higher in southeast Hudson Bay, east Greenland and Svalbard. As with PCBs, there were statistically significant differences only among the two or three highest and lowest areas. This distribution indicates the importance of atmospheric transport from North America and Europe to the North Atlantic. The high concentration of PCBs and other CHCs in the Arctic Ocean bears near Prince Patrick Island may be ecologically based (perhaps greater importance of an under-ice based food chain) or may be due to real differences in concentration of contaminants in the environment.

Distribution of HCHs, CBzs, and methylsulfone metabolites of PCBs and DDE was studied using pooled samples collected in 1989–91. Unfortunately, biopsy samples were used up in analysis of the other CHCs, therefore geographical coverage was more restricted. Geographical distribution of HCHs and CBzs was very even, indicating that these relatively volatile CHCs were uniformly distributed in the Arctic (Norstrom 1994b). Methyl sulfone PCB and DDE metabolites were identified in polar bears (Bergman *et al.* 1994). Their distribution followed the tendency of total PCBs, but the metabolite/total PCB concentration ratio was higher in the west, probably because of a higher

proportion of precursor PCBs (Letcher *et al.* 1995). Contrary to PCBs, the methylsulfone DDE/DDE ratio was higher in the east than the west, which may be of some toxicological significance. The distribution of PCDDs and PCDFs was studied in only a few areas of the Canadian Arctic. Concentrations were lower (<1 ng/kg lipid in most cases) and more uniform than found in 1982–84 (Norstrom 1996a).

There is relatively little consistent information on temporal trends of CHC concentrations in polar bears. Recent re-analysis of archived polar bear samples from 1984 and 1990 from four areas of the Canadian Arctic indicated no consistent trend up or down (CWS unpublished data, Norstrom 1995a). There were no significant temporal changes in PCB concentrations. In north Hudson Bay, samples from 1968 were also available. In this area, concentrations of all CHCs except DDTs were highest in 1984, and were similar in 1968 and 1990. This indicates that peak concentrations of most CHCs occurred at a later period than at mid latitudes following decreased usage or emissions due to controls or bans in most industrialised countries. It is recommended that temporal trends of CHCs in polar bears be monitored by another circumpolar survey at 5–10 carefully chosen sites in 2000.

Since 1993, more efforts have been directed more towards obtaining an understanding of the effects of CHC contaminants in polar bears. The hepatic cytochrome P⁴⁵⁰ (CYP) enzyme system of the polar bear was characterised using various immunochemical probes against rat CYPs in livers of polar bears from Barrow Strait which had been sampled immediately after being killed by Inuk hunters in a study primarily instigated by the Resolute Bay Hunters and Trappers Association to determine the half-life of Telazol (Bandiera *et al.* 1995a). Both inducible (CYP1A and CYP2B) and constitutive CYP isoforms were found to cross-react with anti-rat CYP antibodies. The presence of CYP1A and CYP2B indicates a response of the polar bear to CHC exposure. The next step was to immunochemically quantitate hepatic concentrations of CYP1A and CYP2B proteins and investigate their catalytic activity. Enzyme concentrations and activities were compared to concentrations of CHCs in liver known to be inducers of CYP1A and CYP2B in other mammals (Letcher *et al.* 1994, Letcher *et al.* 1996a, Norstrom 1996b). CYP1A concentrations were highly correlated only to PCBs, and dioxin-like equivalents derived from specific members of this class of contaminants, not to other CHCs, the major one being Chlordanes. EROD activity, CYP1A concentration and PCBs were all correlated at lower concentrations of PCBs. At higher concentrations, EROD activity reached an asymptote, and may even have begun to decline, probably due to

enzyme inhibition by PCBs. One of the more important findings was that CYP2B activity was not highly correlated to either PCBs or Chlordanes individually, even though both are known inducers. Stepwise, backward, multiple regression showed that a linear combination of both PCB and Chlordane concentrations described most of the variance in CYP2B concentrations, strongly suggesting that these two CHCs, the major ones in polar bear liver, were additively responsible for induction of CYP2B. There was a significant unexplained induction, which may have been due to other CHCs, some constituent activity, or residual levels of components of Telazol.

Preliminary data suggest that transfer of methyl sulfone metabolites of PCBs and DDE via milk may be greater than that of the parent compound classes (Letcher 1996c). Concentrations of methyl sulfone PCBs in milk in the early post-natal period were 200 ng/kg lipid. Concentrations of methylsulfone DDE, a potential adrenal toxin, increased in a denning female to 5–10 times the concentration found during active feeding. Three hydroxy PCB metabolites have been identified in polar bear plasma, one of which is also major in humans (Sandau and Norstrom 1996). This indicates that there is probably binding to TTR, the plasma protein responsible for vitamin A transport in blood of most mammals, and thyroid hormones in some species.

Metabolic alteration of PCB patterns and bioaccumulation of PCB and DDE metabolites has been studied in the cod-ringed seal-polar bear food chain in the Barrow Strait area in Canada (Letcher 1996c, Norstrom 1996b). No metabolites were found in cod, in keeping with the expected low metabolic capability of fish for this class of CHCs. Methyl sulfone metabolites of PCBs were found in ringed seal, but precursor PCBs to these compounds were also detected, indicating the possibility that polar bears may bioaccumulate metabolites directly, or form them from bioaccumulation of the precursor PCBs. To help sort out these two possibilities, precursor and metabolite concentrations were normalised to the major recalcitrant PCB in polar bears, CB153. This analysis indicated that bioaccumulation from ringed seal is definitely occurring, since the precursor to one of the methyl sulfone metabolites found in seal and bear was absent in the bear, therefore it could only have been bioaccumulated. However, there are indications that some PCB congeners are specifically metabolised to methyl sulfone PCBs in the polar bear. More research is required.

Based on sensitivity of other species, immunotoxic effects of PCBs are likely to be the most sensitive endpoint for current exposure of polar bears to CHCs. Immuno-toxicology projects are presently being

developed in collaboration with Canadian and Norwegian scientists. Furthermore, the high capacity of the polar bear to metabolise DDE, and the presence of methyl sulfone DDE metabolites in liver of the polar bear, suggests that it is a species that may be subject to the hyperadrenocorticism, which may have been responsible for reproductive failure of seals in the Baltic Sea in the 1970s. A collaborative study with Swedish scientists to study sensitivity of polar bear adrenals to DDT-group compounds and metabolites is underway.

Several reviews of CHC contaminants in the Arctic marine ecosystem were published (Norstrom 1994c, Norstrom and Muir 1994, Muir and Norstrom 1994). Exposure of humans, polar bears and marine mammals to CHCs was compared (Zhu *et al.* 1995, Dewailly *et al.* 1993). A strong correlation between the persistent PCB, CB153, and trophic level (from nitrogen stable isotope analysis) was found for a variety of species. Polar bears are at trophic level 5 and have the highest CB-153 concentrations (Norstrom 1994c).

Future research will concentrate on the effects of PCBs and DDE and their metabolites on immunotoxicity, adrenotoxicity and vitamin A/thyroid hormone homeostasis.

Northwest Territories (NWT)

Population inventory of Baffin Bay, Lancaster Sound, Norwegian Bay, and Kane Basin (with Greenland Home Rule, Parks Canada, University of Saskatchewan)

The population zones referred to as Baffin Bay, Lancaster Sound, Norwegian Bay, and Kane Basin are the old Baffin Bay, Parry Channel, and Queen Elizabeth Islands areas that were formerly polar bear management zones D, F, and G. These areas include Greenland waters. The first phase of this project was to delineate population boundaries using satellite telemetry. The second phase, in its final year, is to estimate population size using mark-recapture methods.

Three satellite radio collars were deployed in April 1991 in Prince Regent Sound. An additional 11 radio collars were deployed between Bylot Island and Cape Dyer, Baffin Island in September 1991. In spring 1992, an additional 3 collars were deployed in Prince Regent Inlet, 10 were deployed along the east coast of southern Ellesmere, Devon, and northern Baffin Island, and 5 were deployed by Greenland in the Melville Bay area. In spring 1993, 3 more radio collars were deployed in Prince Regent Inlet, 25 radio collars were deployed in Lancaster Sound, Jones Sound, Norwegian Bay, Kane Basin, and eastern Baffin Bay, and 5 radio collars were

deployed in Greenland. Four radio collars were deployed south of Cape Dyer in fall 1993. In spring 1994, 27 radio collars were deployed, mainly in the western part of the study area and in Kane Basin. In spring 1995, 2 radio collars were deployed in Eureka Sound.

Delineation of population boundaries

Polar bear movements monitored by telemetry can be used to define population boundaries. The procedure is to deploy radio collars on adult females in a pseudo-uniform fashion over an area sufficiently large to contain more than one population. The movements of the bears are first “flattened” using a Lambert grid transformation, then the movements of each bear are summarised by 4 seasonal modes in the Lambert X–Y grid. A cluster analysis is performed that groups the bears into populations. The choice of populations is guided by the pseudo- t^2 values associated with each cluster. Once the population membership has been identified, the space use of that population can be presented by employing standard home range algorithms. The non-parametric harmonic mean range estimator is preferred. The 50%, 60%, 70%, 80%, etc. contours can be calculated, these data can then be re-transformed back to standard latitude-longitude co-ordinates, and displayed. The degree of overlap can be used to select meaningful population boundaries.

Seventy-nine of the 96 polar bears given radio collars provided data on movements for at least 12 months. The movements of these bears were analysed using the cluster analysis procedure (Bethke *et al.* 1996). The preliminary analysis suggested that polar bears in the Parry Channel and Baffin Bay areas could be divided into 5 populations. The northern population pooled Kane Basin with Norwegian Bay, because of the relative proximity of activity cores on eastern Norwegian Bay and western Kane Basin. However, neither marked nor radio-collared polar bears were observed to move between Kane Basin and Norwegian Bay, so these areas were separated. The indication of 2 populations in Baffin Bay was mainly due to segregation of the northern and southern bears during the ice-free season in fall. Cluster analysis based on spring movements did not support dividing Baffin Bay into 2 populations. In both Canada and Greenland, most polar bears are harvested in spring. For management purposes the Baffin Bay population will be regarded as one unit. The four populations in the former Baffin Bay-Parry Channel population have been named: Lancaster Sound, Norwegian Bay, Kane Basin, and Baffin Bay.

Mark-recapture population estimates

The mark-recapture population estimate portion of population inventory research is conducted by surveying the entire population area identified by telemetry studies with helicopter and snow machine. Every bear seen is captured, marked, and released. The assumption of this capture protocol is that every bear in the population has approximately the same chance of being captured (i.e., geographically uniform = pseudo-random).

A total of 420 bears were handled in spring (Lancaster Sound-Norwegian Bay-Kane Basin populations) 1995 and the sex ratio of adults was 62% females. A total of 434 bears were handled in spring 1996 and the combined adult and subadult sex ratio was 60% females. The fraction of bears already marked in spring 1995 and in spring 1996 was 22.4% and 26% respectively.

A total of 254 bears were handled in fall 1995 and the sex ratio of adults was 36% females. The fraction of bears already marked in fall 1995 was 19.6%. A preliminary total population estimate of cubs and adults combined of 1800–2000 was calculated using a modified Fisher-Ford approach that uses only a subset of the capture data (1994 and 1995) for the annual survival rate and population number estimates. It was recognised that this estimate was based on low estimates of annual survival rate, and 2200 was used as a conservative estimate of total numbers for management purposes. Males appear to be over-represented in the fall capture sample because males tend to concentrate near the coastline, while females tend to be found further inland, especially in high relief areas.

The Baffin Bay mark-recapture work was initially planned for 3 years, but because a large fraction of the population was marked in 1994 and 1995, the field operations for fall 1996 in Baffin Bay were cancelled. The preliminary analyses provided consistent population and survival rate estimates, but no estimate of variance for either parameter was obtained. The estimate of survival rate pooled cub and adult survival, and was recognised as low. Underestimating survival results in conservative (low) estimates of population number. Subsequent analyses have indicated a problem in pooling the marked bears from the 1981–1985 study. Even when the analysis is segregated by sex, and restricted to individuals 2 years of age or older, the estimate of natural (without harvest) survival rate using pooled (1981–1995) data is only 0.88 (J. Laake, personal communication). If the annual natural survival rate was 0.88, the population would not sustain a harvest. More recent data suggest a higher adult annual survival rate, but these data are limited (only two years) because the

project was suspended. Resources are being sought to complete the final year of this study.

Plans for the 1997 research program include a spring and fall field component. Preliminary analysis of population numbers for the Lancaster Sound, Norwegian Bay, and Kane Basin, and Baffin Bay populations are given in the draft Status Table for Canadian Populations in the Canadian management report to the IUCN (Lunn *et al.* this publ.). 1997 will be the final year of mark-recapture work required to provide estimates for the Baffin Bay, Lancaster Sound, Kane Basin, and Norwegian Bay populations. Because there is considerable movement between these populations, they must be surveyed as a unit to avoid capture bias that could distort the population estimates for each area, and the sum of areas. The Lancaster Sound, Kane Basin, and Norwegian Bay mark-recapture work will be done in April-May. The Baffin Bay mark-recapture analysis must be done during the open water season when all polar bears in this area are onshore.

Mark-recapture does not require that all bears are seen or marked. Only 15–30% of the total estimated population needs to be marked to get a good estimate. Once that fraction has been marked, the entire range of the population must be sampled to determine the fraction that are marked, and the fraction that are unmarked. A minimum of 80 bears per population per year need to be captured for an acceptably precise estimate of the fraction marked. The capture samples from contiguous populations are pooled, and a grand total is estimated. Then individual estimates are calculated and compared to determine how the grand total is subdivided into the pooled populations. For small populations, such as Kane Basin or Norwegian Bay, it has been difficult to obtain the large sample sizes required for the target 15% coefficient of variation on the estimates. However, the priority is to reduce bias, which may compromise management decisions more than a lack of precision. There is also the option of continuing studies for a longer period for small populations, and choosing to be more conservative in those areas.

The work planned for spring 1997 will involve both snowmachine and helicopter capture of polar bears. The snowmachine work will occur in late March and early April, mainly from Grise Fiord. The helicopter (Bell 206B) work will begin April 15 and last as long as it takes to survey the entire population areas. The helicopter capture will ensure that all of the areas are covered regardless of ice conditions encountered.

Southeastern Baffin Island

As part of the Baffin Bay study, 7 satellite radio collars were deployed on polar bears along the NE coast of Cumberland sound between Cape Mercy and Cape Dyer. As discussed in the Baffin Bay section above, these bears remained in Davis Strait and their movements overlapped with the movements of bears satellite-tagged in the Labrador Sea. The density of polar bears was high along the SE Baffin coast, suggesting this is an important open-water retreat for Davis Strait polar bears. This population has been targeted for a population inventory as soon as the Baffin Bay inventory is completed and funds are available.

Polar bear movements in Auyuittuq National Park Reserve (with U. of Saskatchewan, Parks Canada)

Steven Ferguson has completed his studies and his findings have been submitted for publication (see Ferguson *et al.* 1997 in publications section). The abstract of the paper, "Space use of polar bears in and around Auyuittuq National Park, Northwest Territories, during the ice-free period" is below.

We investigate patterns of space use for polar bears in and around Auyuittuq National Park, Northwest Territories, during the ice-free period using satellite telemetry and mark recapture, 1991–95. Female polar bears showed a general fidelity to the region, but little site-specific fidelity. The pattern of sea ice ablation influenced when and where bears were forced to leave the ice for land, usually at the end of August. While awaiting the return of sea ice, bears conserved energy by reducing movement and decreasing activity. Bears left the land after ice formed that was strong enough to support them, usually in mid November. During the ice-free period, females with cubs-of-the-year were farther inland, closer to fjords, and less likely to use islands than males. Males found close to females with cubs-of-the-year were thinner than the average male, suggesting that segregation may result from the threat of intra-specific predation. Females with cubs-of-the-year left the ice for land earlier than other classes of bears and rarely used snow shelters. After about a week on land, pregnant females entered a maternal den for the winter. Unlike other polar bear populations, most females with 1-year-olds entered a shelter after about 3 weeks on land and remained there for about 2 months. Dens and shelters were located at high elevations and far from the coast and sheltering bears weighed more than non-sheltering bears.

Inter-annual climatic variability

Fractal geometry provides a technique to measure irregularity in nature's patterns. Euclidian geometry includes standard geometric shapes such as points, straight lines, circles and solid planes. In contrast, fractal geometry deals with the geometry of nature, which has a different level of complexity and describes many irregular and fragmented patterns around us. We can apply these methods to polar bear movement patterns and compare 'stay-at-home' bears and the 'wanderers'. This technique measures the tortuosity of polar bear movements and tests can be made to see if bears of different reproductive classes respond differently to their environment as described by a measure of the fractal dimension of their movement pattern. To the end of 1994, 28 females were instrumented with satellite collars as part of this study.

Ferguson has also published his study on ecological implications of latitude and climatic variability using fractal and chaos theories (Ferguson and Messier 1996) and a review of delayed implantation and grade shifts in North American carnivores (Ferguson *et al.* 1996).

Population modelling (with OMNR, University of Saskatchewan)

A risk analysis simulation model to explore the effects of harvest is being co-operatively developed with the Ontario Ministry of Natural Resources, University of Saskatchewan, and the Nunavut Wildlife Management Board. The model may be run in deterministic or stochastic mode, and can simulate single species harvest dynamics for species with a birth pulse that is annual (waterfowl, ungulates, seals), bi-annual (black bears), or tri-annual (walrus, polar bears, brown bears). The model will allow the user to specify density effects on any sex or age stratum of recruitment or survival parameters, based on user-defined population strata (i.e., subadult males only, all females, total numbers, etc.). In stochastic mode, Monte-Carlo simulations are used to develop variance estimates for various population attributes at a given time. Similarly, a variance to time to extinction could be estimated.

The uncertainty in demographic simulations comes from (1) the underlying variance in rates of birth and death, (2) uncertainty resulting from the binomial or multinomial contingencies existing in demographic processes in nature, and (3) sampling error. The stochastic option is designed to capture all three sources of uncertainty and conduct the Monte-Carlo simulations in a manner that allows the user to estimate the risk of various harvest options.

The model is written in Visual Basic for the MS Windows environment. Most of the programming and documentation are expected to be completed by summer 1997, and the model will be available without charge by agreement with Ontario's Ministry of Natural Resources.

Polar bear deterrent studies

Efforts at research and development of new methods to deter polar bears were hampered by federal legislation and regulations on firearms, possession, and shipping of "hazardous" materials. Essentially everything that will work to deter polar bears might also be used on humans, and is either banned or difficult to procure and transport. The result is very limited potential for individuals to respond to bear attacks on life and property. The researchers encountered great difficulty in importing deterrent products, or even the materials to manufacture deterrent products.

About 85% of the defence kills in the Northwest Territories are due to aboriginal hunters. The research and development program was aimed at producing practical polar bear deterrent devices that would be sufficiently portable and robust that they would function in camp situations. Most hunters have and carry a shotgun and rifle, so firearm-based deterrents were emphasised. Many new products on the market that would be both practical and useful for deterring polar bears are manufactured for police use, and are classified as restricted weapons. Of the devices explored, shotgun based "scare shells" using star shells and fire crackers were about the only effective deterrent available. These devices do scare some polar bears away, but typically the bears become accustomed to the flash and the noise, and return.

As previously reported, capsicum aerosols were not effective at cold temperatures. The performance of the spray was also cold-dependent. The aerosols were uniformly worthless as a polar bear deterrent in the windy cold conditions of most polar bear encounters. A shotgun-based capsicum shell using powdered capsicum was located and obtained, but has not been tested.

Exploding marker darts have also been tested. These darts are rubber tipped, and do not penetrate the skin at any range. When they hit, they ignite flash powder that detonates with a loud bang. A superficial slap is delivered at the same time. Test samples were for the .50 cal. dart rifles only, but these could be manufactured for use in shotguns, and offer some promise for long-range deterrent potential.

Capture and handling has been effective in encouraging problem bears to leave outpost camps and communities. Several Parks and Renewable Resource Officers have been equipped with capture equipment that they are using in deterrent efforts. All 42 problem polar bears handled during the study left the area upon recovery, suggesting this method may be very effective when trained personnel and suitable equipment are available, and when the bears have not been habituated to human settlements.

The Polar Bear Management Agreements and Memoranda of Understanding (MOU) indicate the Department will work with the Hunters and Trappers Organizations (HTOs) to develop better methods of deterring problem bears and protecting property and meat caches on the land. The Agreements and MOUs also indicate the Department and HTOs will work together to identify methods of compensating hunters that suffer losses from polar bears. The communities of Clyde River and Broughton Island on northeastern Baffin Island have a particularly large number of bear incidents during the fall open water season. Each community has approximately the same number of polar bear encounters as Churchill, Manitoba per year. However, there has been no dedicated bear deterrent program to assist these communities.

After consultation with Clyde River and Broughton Island, a deterrent and compensation program was developed. This program will likely serve as a model for the development of programs for other communities and perhaps for Nunavut.

Ontario (OMNR)

Research activity in Ontario during 1993–1996 was restricted to monitoring populations by conducting aerial surveys. Surveys were flown in late summer each year on the Hudson Bay and James Bay coasts, and in February and March in 1994 and 1995 to monitor the number of females emerging from inland dens.

Late-summer aerial surveys

Aerial surveys to monitor the number and distribution of polar bears along Ontario's coast have been conducted annually in late August or early September since 1963. Surveys were flown 29–30 August 1993, 30 August–2 September 1994, 28–30 August 1995 and 26–29 August 1996 using a deHavilland Twin Otter flying at the high tide mark at about 130 m AGL and 200–220 km/h ground speed. A pilot, navigator and three rear observers were used to count bears. Weather conditions were generally favourable for sighting bears in all four years, although the area from the Severn

River to the Ontario-Manitoba border was not surveyed in 1993 because of persistent fog and rain. This is the only year from 1963 to 1996 that the coast was incompletely surveyed. The total number of bears sighted was 157 in 1993 (incomplete survey), 254 in 1994, 240 in 1995 and 203 in 1996 (Kolenosky and Obbard 1993, Obbard 1994, 1995, 1996). Based on recent numbers of animals sighted, had the 1993 survey been completed the total count that year would have been around 200 bears (Kolenosky and Obbard 1993).

In addition to the coastal areas between Hook Pt. and the Ontario-Manitoba border, the survey extended to the James Bay coast between Hook Pt. and Ekwan Pt., and to Akimiski Island when weather conditions were favourable. From 1994–1996, the chain of islands in the middle of James Bay including North Bear Island, Bear Island, South Bear Island, Sunday Island, Grey Goose Island, Spencer Island, Walter Island, North Twin Island, and South Twin Island were also surveyed. Bears were observed along the coast south of Hook Pt., on Akimiski Island, and on North Twin Island and South Twin Island in each of 1994, 1995, and 1996, emphasising the importance of these locations as summer refuge for polar bears. In 1994, bears were also sighted on Bear Island and on Spencer Island, suggesting that at least some of the smaller islands in James Bay were used occasionally as summer refugia. The total number of bears sighted including those seen on offshore islands in James Bay was 298 in 1994, 299 in 1995, and 231 in 1996 ($\bar{x} = 276$).

Despite large variation among years in the number of bears sighted during the late-summer survey, there was a significant increasing trend in the count from 1963 to 1990. This trend appears to have continued. The mean number of bears sighted in the late-August survey in the area between Hook Pt. and the Ontario-Manitoba border from 1990–1996 ($\bar{x} = 192.9$, $SD = 50.5$) was significantly greater than the mean number of bears sighted in the period 1963–1989 ($\bar{x} = 107.1$, $SD = 43.5$) ($t = 4.359$, $P < 0.001$). The number of bears counted during the annual survey is generally considered to be an unknown proportion of the total population. However, during a 3-year mark-recapture study from 1984–1986, the sighting frequency of bears marked with paint marks was about 20% during the annual aerial survey. If that proportion is reliable, then about 20% of the population is sighted along the coast each year, and the current population estimate of 1000 for the Southern Hudson Bay population is supported by Ontario's recent annual aerial survey results (Mean annual number of bears sighted = 192.9, which gives a population estimate of 965 based on 20% sighting probability.) If the bears sighted south of Hook Pt., on Akimiski Island, and on the offshore islands in mid James Bay are factored in,

the average number of bears seen from 1994–1996 (276) would yield a population estimate of over 1000 animals. However, there is no estimate of the sightability of bears in these latter areas from the mark-recapture study conducted in the mid 1980s, so it is not possible to convert this total number sighted to a population estimate.

Late-winter aerial surveys

Aerial surveys to monitor the number of females with cubs emerging from inland maternity dens were conducted in 1994 and 1995. Three surveys were flown at about 2-week intervals in late February, early March and late March in each year. Standard transect lines parallel to the coast vary from 6.4 km apart close to the coast to 12.8 km apart farther inland. Lines were selected to ensure coverage up to 100 km inland. When polar bear tracks were seen they were circled to obtain a count of the number of animals in the family group and to estimate the age of tracks. Multiple observations of the same family group seen on successive transects were determined based on location, track age and the number of cubs in the group. Thus, a conservative estimate of the number of family groups was developed.

In the area between Hook Pt. on James Bay and the Ontario-Manitoba border a minimum of 49 family groups was observed in 1994 and 53 family groups in 1995. Mean litter size (based on visual observations and counts of unambiguous tracks) was 1.70 in 1994 ($n = 27$) and 1.62 in 1995 ($n = 42$). Only one litter of three cubs was observed in each year. These results are similar to the pattern found from 1974–1978 and from 1984–1987. Family groups were also observed on Akimiski Island, North Twin Island, and South Twin Island in James Bay in both years (6 in 1994, 10 in 1995) emphasising the importance of these areas as additional denning areas for the Southern Hudson Bay population. These records represent the most southerly known denning areas for polar bears (*ca* 53°N).

Canadian National Parks

The Department of Canadian Heritage, Parks Canada manages National Parks and National Historic Parks and Sites throughout northern Canada. The *National Parks Act* (1988) and National Park Policy state that National Parks will be managed to maintain the integrity of the ecosystems they represent.

An educational brochure about polar bear safety has been produced and is distributed to all visitors. As well, visitors to National Parks in the Arctic are required to register with park staff prior to entering the parks. This process provides an opportunity to personally educate

visitors about polar bears and discuss how to avoid conflicts with bears. All observations of polar bears or their sign by park staff, visitors and local people are entered into a GIS-compatible wildlife sighting database. Maps of polar bear sightings in Auyuittuq National Park Reserve (NPR) are produced and updated annually and are used to educate and inform visitors about relative levels of risk associated with specific areas.

From 1993–1996, Parks Canada supported and participated in a study of space use by polar bears in and around Auyuittuq NPR (previously summarised in this paper), conducted in co-operation with the NWT Department of Resources, Wildlife and Economic Development, University of Saskatchewan, local Hunters and Trappers Organisations and the Greenland Home Rule Government. The results of this study will be used to identify likely denning areas and risk zones within Auyuittuq NPR. This zonation will be used to manage the distribution of visitors to minimize impacts on denning female bears and reduce the potential for bear-human conflicts. In addition, Park Wardens and NWT Renewable Resource Officers have co-operated on spring denning surveys in and around Auyuittuq NPR since 1991.

Establishment of Wapusk National Park in Manitoba will bring an additional management agency into the Western Hudson Bay polar bear population. The park agreement sets up a management board that includes 2 members each from the Government of Canada, the Churchill LGD, Fox Lake First Nation, the Government of Manitoba, and York Factory First Nation (listed in alphabetical order). The management board recommends to the Federal Minister on matters relating to the planning, management, and operation of the park. Additionally, Manitoba must consult with the management board on matters within the provincial Crown lands that may affect park lands and resources. The management board will also recommend to the Federal Minister on research, including procedures, criteria and priorities. Further, the management board shall develop recommendations related to “resource management, including harvesting activities, research and other proposed actions that may impact on ecosystems, wildlife habitats or populations . . .” (Management Board section 13 a from the Federal-Provincial Memorandum of Agreement for Wapusk National Park). The agreement contains a section specific to research. Its articles deal with encouraging research that meets needs for the planning and management of the Park land, priority for Manitoba Keewatinowi Okimakanak, Inc. and Churchill Northern Studies Centre for provision of contracted research, operation and establishment of field camps, and the respecting of research components of international agreements in effect in the area of the park.

Parks Canada recognizes the value of basic ecological research, and the unique long-term nature of studies on polar bears and other subjects within Wapusk NP. To address concerns about jurisdictional constraints on research, a research co-ordinating meeting was held at the Churchill Northern Studies Centre in Churchill, Manitoba on August 26, 1996. Parks Canada staff and researchers from a variety of disciplines met to discuss mutual concerns about the management of research, and research priorities for park management needs.

University of Saskatchewan

Body composition, size, and reproduction

In January, 1996, Stephen Atkinson successfully defended his Ph.D. thesis “Ecophysiological studies of body composition, body size and reproduction in polar bears (*Ursus maritimus*)”. The abstract from his thesis follows:

The nutritional ecology of polar bears is characterised by wide annual variation in rates of food intake, ranging from hyperphagia to prolonged periods of fasting. A fundamental adaptation to fasting, thought to be well developed in bears and in particular polar bears, is an ability to minimize the net catabolism of body protein whilst relying upon lipids as a source of energy. Data are presented, however, which suggest that the efficiency of protein sparing in polar bears is not fixed, but varies according to the body composition of individuals at the on-set of a fast. As a simple consequence of their obesity, fatter bears are able to derive a lower proportion of their energy demands from protein catabolism. These findings are discussed with reference to previous studies of fasting in other bear species.

Due to their “feast-or-famine” existence, female polar bears are one of the few mammals known to regularly fast for extended periods during reproduction. Maternal body condition (fat content) is thus shown to exert a particularly strong positive influence on reproductive performance during such fasts. In addition, maternal age is found to be positively associated with reproductive performance, both indirectly through its relationship to maternal condition and also directly. Evidence that lactational performance is affected by age, independent of condition, is consistent with the hypothesis that reproductive effort increases with age.

As polar bears are polygynous and sexually dimorphic, relative body size probably plays an important role in male mating success. Consequently, theory predicts that mothers in good condition should invest more in male than female offspring, to produce males that are large as adults. Differences in size arising during early

life (when cubs are largely dependent on their mothers for nutrition), however, are shown to be a much weaker determinant of relative adult size among males than females. It is proposed that the prolonged growth period of males, relative to females, predisposes growth in males to a greater degree of environmentally mediated variation and thus reduces the potential for mothers to influence the adult size of male offspring through a strategy of biased investment.

Intermediary metabolism of polar bears

For many mammals, including humans, obesity and starvation are often associated with morbidity (e.g. Type II diabetes mellitus, hypertension and coronary heart disease, etc.) and mortality. Polar bears, however, oscillate annually between these two states without any apparent consequence to their health. In 1993, the United States National Science Foundation provided funding for a 4-year study on the protein-sparing adaptations of polar bears during prolonged fasts. Specifically, the principle regulatory pathways of fat, carbohydrate, and protein metabolism in polar bears and the implications of long term fasting on their life history strategies will be determined through the use of stable isotopic tracers and clinical chemistry. As well, understanding the interactions between lipid and carbohydrate substrates in this species should provide insights into of the health risks associated with obesity and starvation.

In most fed mammals, the proportions of nutrients (e.g. protein, carbohydrate, and fat) oxidised for energy are determined, in part, by their relative proportions in the diet. Fatty acid oxidation is spared in humans and many other mammals by the consumption of high-carbohydrate diets. This is because high concentrations of blood glucose and insulin inhibit lipolysis in adipose tissue, so free fatty acid (FFA) levels remain low. As a mammal passes from the fed to the fasting state, dietary carbohydrates decline and liver glycogen stores are mobilised to maintain blood glucose levels. Herein lies the central dilemma faced by fasting mammals: they require a small, but significant level of carbohydrate for anaerobic energy production and as a reserve for glucose-dependent tissues, particularly the brain. However, the largest energy stores of mammals exist as lipids that cannot be made into glucose, except for the glycerol moiety of triacylglycerols that contributes only a small amount to glucose production.

In fasting mammals, glycogen supplies in the liver are usually exhausted within 24 hours. The resulting glucose deficiency is resolved in 2 ways: (1) in fasts of relatively short duration, the liver synthesises glucose (gluconeogenesis) from amino acids (primarily alanine)

derived from muscle protein; and (2) in prolonged fasts, the body relies increasingly on oxidation of FFA and ketoacids derived in the liver from fatty acids. These fat-derived fuels can reduce the non-obligatory oxidation of glucose (e.g. replace about 80% of the glucose required by the brain) and thereby spare body protein. The response of most mammals to starvation follows a gradient between an initial adaptive physiologic response and a terminal pathologic response. As fat stores are depleted, however, the terminal stage of starvation is entered and protein is again catabolized to meet gluconeogenic requirements.

During the past 2 years, some striking aspects of lipid and carbohydrate metabolism in polar bears were noted. In contrast to most other mammals, glucose is not a limited substrate during the prolonged fasting of polar bears. In fact, serum glucose and liver glycogen concentrations appear to increase during a fast. Nonetheless, net lipolysis is occurring at a significant rate during a fast (i.e. 0.3–1.0 kg fat are lost per day), although there is no evidence for increased fatty acid oxidation or ketogenesis. Paradoxically, serum FFA concentration and serum acyl-carnitine/free carnitine ratio show no change, and serum ketone bodies remain low throughout the year. It is suggested that fasting polar bears utilise fatty acids to supply the substrates for gluconeogenesis and net protein synthesis, and that energy is derived both from glucose and fatty acid oxidation.

Studies on Telazol

This study was undertaken to determine how long drug residues from Telazol (equal parts of tiletamine hydrochloride and zolazepam hydrochloride) are likely to remain in tissues and fluids of polar bears after immobilisation. Samples of serum, muscle, fat, kidney, and liver were collected from polar bears killed by Inuk hunters out of Resolute at fixed times after the bears had been immobilised with Telazol.

After interfering peaks occurred in some samples, the extraction procedure for serum samples was modified to include a back-extraction step. A procedure for extraction of the drugs from tissue samples has also been developed.

Scanning of samples from different bears revealed interfering peaks not visible on chromatograms from the original test samples used to develop the analytical method. Therefore, the conditions were changed to give effective separation of all peaks. The limit of quantitation was 10 ng/ml for tiletamine and 2 ng/ml for zolazepam, while the detection limits were 5 and 1 ng/ml, respectively.

Both zolazepam and tiletamine were eliminated from serum and other tissues at differential rates. However, concentration levels of both drugs declined very rapidly from all tissues during the first few hours post-injection. The rate of elimination slowed as concentrations decreased for all tissues. The immobilisation agent (tiletamine) was not detected in the serum one day after immobilisation. The tranquilliser (zolazepam) was not detected in the serum 2 days after immobilisation, which is consistent with earlier observations that recovering polar bears could rise and move about, but did not seem aggressive or disturbed.

Both drugs lasted longest in the fat and the liver (which is not consumed by humans), with high (>300 ng/g) levels of tiletamine recorded in the fat of one bear 5 days post drugging. However, only trace levels (<100 ng/g) were found in other tissues more than 24 hours post-immobilisation, suggesting that any meaningful hazard from consumption of the edible tissues had been eliminated in about one day.

Ruling on consumption by humans

Evidence of metabolic by-products from Telazol were detected, but specific individual metabolites were not identified or quantified. The characteristics and longevity of these by-products are unknown, which was a factor in the decision by Health and Welfare Canada to require that immobilised polar bears not be consumed by humans for one year. Health and Welfare Canada stated that this long withdrawal period would remain in effect until more definitive toxicological and residue depletion studies could be conducted to support a shorter withdrawal period.

All polar bears handled in Canada are marked on the fur to ensure that Inuk hunters will recognise them as recently-immobilised animals. Compensation for loss of meat is paid in most jurisdictions.

Reversible immobilisation of polar bears with medetomidine-zolazepam-tiletamine and atipamezole

Zolazepam and tiletamine, in a 1:1 combination by weight (Telazol or Zoletil), has been the preferred drug for immobilising free-ranging polar bears over the past 10 yr. When used in this species, the drug combination results in a relatively short induction time (e.g. generally <10 min), reliable and predictable immobilisation, little adverse physiological effect, and safety in handling for personnel. However, there are some disadvantages to the combination that include lack of a known antagonist (to tiletamine), potential for lengthy

recovery, and minimal analgesia at the dosages required for satisfactory immobilisation.

During 1995, a study to develop a new drug combination for immobilising polar bears was initiated to determine whether drug combinations that included the potent antagonist medetomidine could eliminate the shortcomings experienced with the combination of zolazepam and tiletamine. Medetomidine drug combinations have been shown to be effective immobilisation agents in many non-domestic mammals, including captive polar bears. As an adjunct to anaesthesia, medetomidine significantly reduces the amount of other anaesthetic agents required, therefore, when it is used in free-ranging mammals, it might minimise the occurrence of prolonged recoveries. In addition, the potent sedative effect of medetomidine is rapidly and smoothly reversed by administering the antagonist, atipamezole. Finally, medetomidine is a potent analgesic and this property is one of the features that provides its basis for clinical use.

During 1995 and 1996, 51 free-ranging polar bears along the western coast of Hudson Bay, Canada, were immobilised with a combination of medetomidine, zolazepam, and tiletamine (MZT). Immobilisation with MZT was characterised by a short induction time, low volume, reliable and predictable immobilisation and reversibility, adequate analgesia, and relative safety in handling for field personnel. Few adverse physiological effects were observed in any polar bears with the exception of a single bear that convulsed and died shortly after it was reversed from anaesthesia with atipamezole. Death followed marked hyperthermia (rectal temperature 25 min after reversal was 42.6°C), which was probably a consequence of prolonged (approximately 8 min) and intense convulsions that commenced without premonitory signs 2 min after the bear was fully reversed. During the period of anaesthesia, the polar bear displayed strong, stable physiologic function (based on heart and respiratory rates, haemoglobin O² saturation, and rectal temperature). It is unknown what incited the convulsions and no indication of convulsive behaviour was seen in other polar bears receiving MZT and atipamezole. MZT appears to be an effective drug combination for immobilising polar bears. However, because of an unexplained mortality, further investigation of the physiological effects of MZT and atipamezole is warranted.

Polar bears in the Polar Basin (with US Geological Survey)

Between late July and early September 1994, Malcolm Ramsay and Sean Farley (Washington State University) participated in a joint US-Canada scientific

oceanographic voyage across the Arctic Basin. Dr. Gerald Garner with the USGS collaborated on the studies. Seven bears were sampled and two satellite collars deployed. The cruise was terminated prematurely because of damage to the US icebreaker.

Knowledge of the distribution and abundance of polar bears and other marine mammals is limited to a narrow strip along the southern periphery of the arctic basin. The spectre of significant changes in polar sea ice dynamics as a consequence of global warming bodes ill for the ice-associated marine mammals. The 1994 voyage offered a unique opportunity to further our understanding of the relationships between sea ice and marine mammals, particularly in the regions of multi-year ice. Such information is needed before we can generate a predictive theory of how global warming will affect polar marine mammals. The specific objectives for the voyage were:

1. To determine the concentration of heavy metals, PCBs, and other organochlorine contaminants in adipose tissue, blood, and hair of polar bears. The contaminants in the tissues of polar bears reflect an integration and bio-magnification of what is found within their environment. Samples were collected from 7 polar bears. Analyses will be carried out in the laboratory of R. Norstrom (CWS).
2. To determine both short and long-term dietary data on the food chain used by the bears through determination of stable isotope signatures (^{13}C and ^{15}N) from tissue samples of polar bears and from biological samples collected by oceanographers on the voyage. These trophic level data will allow us to compare the food chain dynamics of polar bears living high in the arctic basin with those of polar bears living closer to shore and will allow us to refine our picture of the kinetics of toxicological contamination kinetics in polar bears. Samples were collected at every station along the route.
3. To compare the annual movements of individual polar bears living in the Central Arctic basin with those of previously-monitored animals living closer to shore. Satellite radios were deployed on 2 adult females. Unfortunately, the radios only functioned for a few months before failing.
4. To work closely with ice physicists and physical oceanographers on board the ships to determine the characteristics of ice types and the bathymetry of the ocean in regions where polar bears are found. Such data are poorly known, yet may be important for assessing the impact that global warming of the Arctic will have on polar bears.

Organochlorine kinetics

Susan Polischuk (Ph.D. candidate, University of Saskatchewan) is using innovative micro-analytical techniques developed specifically for use on polar bears to determine organochlorine body burdens for each bear. Temporal data are being obtained from selected bears handled on two occasions during a fasting period. Blood, adipose tissue, and milk samples were obtained from all bears for the biochemical and toxicological analysis. Spring 1996 was the last field sample.

Organochlorine compounds, such as PCBs, accumulate in lipophilic tissues, and the total body burden is presumably affected by the historical nutritional history of the animal. Polar bears feed at the top trophic level on a marine food chain and are exposed to relatively high levels of contaminants. They also experience large seasonal changes in body composition. Body mass of individual polar bears can more than triple during a relatively short period of hyperphagia and adipose tissue may constitute more than 50% of the total body mass. After extended fasting, adipose tissue depots may be reduced to less than 10% of body mass. Consequently, polar bears may be an ideal model to examine changes in organochlorine concentrations and burdens with changes in total body composition.

Concentration of PCBs in adipose tissue tends to have an inverse relationship with percent body fat, but there seems to be an equilibrium between PCB concentration and weight of fat that is reached at around 80 kg of body fat. Polychlorinated biphenyl body burden of bears did not show a relationship with percent body fat and kilograms of body fat. Females that had a higher percent and weight of body fat did not necessarily have the highest PCB body burden. As adipose mass was lost, some bears decreased their PCB body burden while most bears increased the concentration of the contaminant levels in the adipose tissue.

Two female polar bears that were pregnant in summer and had cubs the following spring showed a significant decline in mean percent body fat while their mean PCB concentrations increased. When sampled over a considerably shorter interval, females with COYs showed a similar trend, with PCB concentrations rising and body fat declining. Although sample sizes are small, there were no significant changes in PCB body burdens among the different reproductive classes between the start and end of the fasting period.

All individual bears sampled sequentially showed increases in PCB concentrations during fasting. Polychlorinated body burdens were variable, some bears showed small declines or increases and some

burdens remained the same. Two females with neonates in spring decreased their PCB body burden by 7% and 28%. The body burdens of females with cubs stayed relatively constant over a 2–3 month period except for one bear who had the lowest fat reserves before and after fasting, 25% and 13% respectively. Within the 2–3 month period, this bear decreased her PCB body burden by 41%. It appears that female polar bears can decrease part of their burden during pregnancy and the early stages of lactation. Since these compounds are being transferred directly to the cubs, then cub survival and growth could be compromised. The next goal is to analyse tissue samples from fasting male polar bears to see whether the kinetics of organochlorine body burdens differ from those of females since males do not undertake pregnancy and lactation.

Although non-pregnant females and cubs feed little over the summer-autumn period and fat reserves are mobilised to meet energy demands, total body burdens of organochlorines did not decline except for one bear with low reserves. Although the sample size is low, it seems plausible that once a bear becomes stressed due to lower than average fat reserves, the organochlorines are metabolised after release. Because of the much shorter time between sampling, no conclusions can be drawn about the over-winter rates of PCB clearance in non-pregnant females.

Feeding status, reproductive status, body condition and age can all affect the kinetics of organochlorines stored in body tissues. It seems prudent, therefore, that biological factors should be considered when trying to interpret chemical analyses. Field work is being conducted in Churchill during a time when feeding is limited and on the sea ice near Resolute during a period of hyperphagia. Two papers had been produced by 1995.

Social interactions of polar bears during their period on land

The objective of this study was to examine the intra-sexual interactions of polar bears outside the breeding season and determine the significance of these interactions to the ecology of this species. Polar bears are considered asocial, yet males on the coast of western Hudson Bay spend several months each year in highly social groups. In the fall they aggregate into groups of 2–14 while waiting for the sea ice to form, and do not merely tolerate each other's presence but interact non-aggressively, spending a great deal of time in apparent "play fighting". Injuries rarely occur during these play interactions, even though males often engage in prolonged vigorous interactions. The apparently amicable associations observed outside the breeding period contrast to the strong intra sexual conflict that occurs during

the spring breeding season. These apparent contradictions suggest that the polar bear has a complex social system. However the significance of such highly cohesive male groups in the "asocial" species has never been examined. Thus, we are currently examining the intra-sexual interactions of males outside the breeding season to determine the significance of these interactions to male fitness.

In October and November 1994–1996, polar bears were observed from tourist tundra vehicles near Churchill, Manitoba. Some bears were marked with a small distinctive pattern of paint or wax. Others were identifiable through natural marks and scars. Observations suggest that male-male interactions (play fighting) include many aggressive components. These components vary in frequency among different individuals or dyads. Preliminary data from this site suggest that males, despite assumed low circulating testosterone levels, are capable of inflicting wounds on each other. In addition, preliminary data also suggest that males may have a dominance hierarchy. To date the observations suggest that the interactions occurring among males are much more complex than any published account, including dominance relationships among individuals and assessment of potential competitors. Future field seasons will expand on this work with the larger goal of investigating the mating system of the polar bear.

The second objective of the study has been to investigate human-bear interactions. Large congregations of polar bears in the Churchill area have been the centre of a growing tourist industry, which has increased the contact between bears and people. With these increased human activities occurring in the same area as the polar bear aggregations, it is important, from a management and conservation perspective, to understand the impact these perturbations are having. However, little is known about what effects such exposure may have on polar bear behaviour, use of space, and energetics. A preliminary investigation of the effects of tourist vehicles on bear activity suggests that harassment of bears at this time of year, when polar bears are fasting, may be particularly stressful.

University of Alberta

DNA studies using microsatellites (with CWS)

David Paetkau has developed primers that allow the populations of bear species to be examined for relatedness. He has worked with black bear and grizzly bear DNA, and has recently completed a comparison of polar bear DNA from the Western Hudson Bay, Davis Strait, Southern Beaufort, and Northern Beaufort Sea populations. Even the two Beaufort Sea populations could be

separated on the basis of microsatellite characteristics, though not at a statistically significant level. A preliminary paper on this work (Paetkau *et al.* 1995) has been published. More detailed studies are ongoing.

Paetkau is now conducting Ph.D. research on population discreteness of polar bears, based on analyses of microsatellite DNA. In 1995 and 1996, samples for DNA analysis (mostly of skin plugs, but also blood) collected by the NWT, the University of Saskatchewan, and CWS were processed. With the co-operation of researchers in the United States, Norway, Greenland, and Russia, adequate samples have been collected to assess population discreteness throughout the circum-polar Arctic. Processing and analyses of population assignment will be completed in early 1997.

Manitoba

The Manitoba Department of Natural Resources has not flown any denning surveys since 1990. They continue to support and assist researchers on approved studies in the western Hudson Bay area.

Churchill Polar Bear Alert Program

Although it is mostly a management program, the Churchill Polar Bear Alert Program is an important source of data on polar bears in the vicinity of Churchill, Manitoba. Each year, bears that approach too closely to the town area are held until the ice forms, or are airlifted away from the townsite. Every bear is marked and measured as part of the overall mark and recapture program in western Hudson Bay, and the data are logged with the National Polar Bear Database. In the past 10 years, the general pattern of handled bears has been a preponderance of subadult bears, with captures of male bears surpassing captures of female bears in both adult and subadult age classes. Although more adult females than adult males were captured in 1995 and 1996, subadult females have never surpassed the number of subadult males in the past 10 years.

Quebec

Makivik

Since most hunting of polar bears occurs in the NWT, and the species is not considered by provincial authorities to be of management concern, scientific research in northern Quebec is limited. The number and sex of bears taken by the communities are reported annually to the provincial Department of Environment and Wildlife (MEF). Hunters are paid for sending skulls (with teeth for determining age) to the provincial agency. Samples of muscle from the tongue and masseter from these

bears have been used to isolate larvae of *Trichinella* spp. In 1996, these larvae were sent to Agriculture Canada (Saskatoon) for identification of the strain. The samples are also used as positive controls in the diagnosis of *Trichinella* in walrus meat at the Kuujuaq Research Centre.

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Issues Pertaining to Polar Bear Management in Greenland

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Hunting and fishing are primary occupations in certain parts of Greenland. In areas where a marked decline in coastal fisheries has forced an increasing number of people to concentrate more effort on hunting, hunting is a combination activity linked with fishing. Many families are dependent on hunting for winter food supplies. Until recently, hunting of polar bears was open to everyone, and was only limited to certain periods of protection and regulations. Catches were registered by special local agents (catch report accountant), but since hunters were not required to report their catches, the registration was dependent upon the effectiveness of the local agent. Gradually information on catches ceased to be reported by an increasing number of settlements, even entire municipalities. The reporting of catches, which started in the middle of the previous century, became erratic and eventually quite unreliable. To re-establish reliable catch data, the Greenland Home Rule introduced a new system for mandatory reporting of catches in January 1993.

The sale of catches is not organized in Greenland. Individual hunters have to arrange for the sale of their catches, and the required catch report paperwork is often neglected. Until recently, hunters were not obligated to do any paperwork, but more rules have been gradually introduced relative to individual species hunted. The rules had to be stricter before the users began to apply them. It became increasingly more difficult to be a hunter: opportunities were reduced while the number of obligations increased. Hunting has evolved from being a tough but relatively free profession, to a job involving much paperwork. Certain catches must be measured and weighed, and biological samples must be taken. Additionally, forms must be completed and dispatched, and catches must be registered. This registration requires a period of introduction and adaptation.

The proportion of reports sent in has been surprisingly high. However, management authorities realize that a high reporting percentage is not enough. The quality of the reports must be improved. One problem is the lay-out and content of the reporting forms and the number of species to be reported. Another problem is the differences in the names for various birds and animals used in the dialects of the various regions, which may conflict with the "standard language" used on the forms. Therefore, the quality of the reported data must be improved, while adequate time must be allowed for

people to adapt to the new rules and obligations. Initiatives for improving quality have been launched. However, it will probably take some time before the quality of the catch reports becomes reliable enough for research and management purposes.

Hunting of Polar Bears

Until recently there were no restrictions on hunting of polar bears in North-West and East Greenland. Anyone seeing a polar bear was entitled to kill it. For this reason there were, and to some extent there still are, various local traditions linked to this animal. The open hunting of polar bears was not stopped until in the mid-1960s. Since then, only professional hunters have been allowed to hunt polar bears.

In East Greenland, and to some extent South Greenland, the traditional rule that the person who first spots a polar bear is also the one who "catches" it, i.e. the one who gets the skin and the meat irrespective of who actually kills the bear, is still upheld. It is therefore possible to encounter very old people and small children who talk about bears they have recently caught. This tradition encourages everyone to be alert for bears, especially in periods when bears are expected to be present.

The new requirement that only professional hunters with valid licenses are allowed to catch polar bears is in conflict with this tradition. The old tradition is being upheld, although hunters have difficulty coping without the income they can derive from the bears they catch. The tradition is acceptable if the bear is shot by someone who is entitled to hunt bears. The conflict is therefore a conflict of a financial nature rather than a conflict between tradition and modern administration. Hunting is a low income profession and as financial obligations increase, it may become difficult for some hunters to surrender the bear to some chance person, given that the sales value of the bear may equal several months' income.

Bears are caught regularly in three areas in Greenland: East, North, and South Greenland. In the first two areas, hunters regularly hunt bears far from their homes, usually in the winter. In South Greenland, bears are caught opportunistically, usually in the field ice, on the mainland, or on islands in the field ice period during

spring and summer. Meat from polar bears is considered a special treat throughout Greenland.

The value of polar bear skins, even substandard skins, is significant to the financial situation of a hunter family. Many seal skins would have to be sold to equal the value of a bear skin. In certain periods of the year the income from skins may ensure a family's upkeep for several months. However, there are distinct regional differences in the use of the skin. In East Greenland almost all bear skins are put up for sale in the market and bear skin trousers are uncommon, or even rare in this region of Greenland. The elite hunters may have such trousers, but they are usually the only ones who uses skins for this purpose. In contrast, most bear skins are used for clothing in North-West Greenland, i.e. in Avernoersuaq and Upernavik. In these areas bears are hunted on long sledge trips. When a bear is shot and cut into pieces, the skin is divided into various shares on the spot. Skins are divided in one manner when two hunters are involved, in another manner when three hunters are involved, and so forth. This tradition is practical from a transportation point of view, since the weight of the skins is distributed "democratically" during the entire trip. The meat is divided in a similar manner, so that those participating in the hunt carry their share of meat, which is used for human consumption and as dog food. To people from the Avernoersuaq and Upernavik areas, the bear skin is of greater practical value than direct monetary value. Clothes made from bear skin are the best clothes sledge drivers can wear, since they sit on the sledges for long periods of time at temperatures of 30–40 Celsius below zero. In these areas every hunter wants bear skin trousers, which are part of the typical local costume in Avernoersuaq. Even in the Upernavik area it is quite common that boys are given bear skin trousers at a very young age.

The Great Greenland tannery buys all skins for sale in the market, including summer skins of low quality. Market conditions are often difficult and consequently the interest in bear skins from this area is limited. In a parallel development, biologists are interested in ending summer bear hunting due to the disturbance of single female bears and females with cubs. However the low earning potential of hunters, particularly in East Greenland, makes summer hunting of bears economically justifiable to the local economy. For some hunters a bear shot in the open-water period may represent a full income for one month, or even for the entire summer. There are no simple solutions to this problem, and it will require clear biological indications of a population decline before the elimination of summer hunting would be acceptable in these remote arctic areas.

The low quality summer skins, which are difficult to sell, could be used for several locally produced products. Claws could be used in handicraft production. Hair of the fur could be shaved and used for beautiful and expensive flies for anglers, which can be sold everywhere, provided that adequate publicity is expended. This product does not require much space, it is light in weight, and is much in demand by connoisseurs throughout the world.

As mentioned, Great Greenland is not particularly interested in summer skins or skins from polar bears in general. However, people in a large part of the sledge dog areas in north-western Greenland are very interested in untreated bear skins which can be used for trousers. It might be feasible to sell untreated, naturally dried summer skins from polar bears for use in trouser production directly from Illoqqortoormiut where the use of polar bear skins for trousers has practically ceased. One large bear skin is enough for 2.5–3 pairs of trousers.

Hunting licenses

The Greenland Home Rule introduced hunting licenses in 1993 which restricted access hunting of species with limited quotas or species regulated in other ways. Since 1993 all hunters are personally responsible for reporting their catches. At the same time, two hunting license categories were introduced: licenses for commercial hunters and licenses for non-commercial hunters. In order to obtain either license, hunters must meet certain requirements. Commercial licenses allow holders to hunt certain species which are subject to quotas. Everyone who applies and meets the criteria is entitled to a non-commercial hunting license, which authorizes hunting of species not subject to quotas.

In 1996, approximately 6,000 non-commercial and 4,000 commercial licenses were issued. A commercial hunting license is issued to anyone engaged in a fisheries-related trade, which is the reason for the large proportion of commercial hunters. However, this distribution between the two categories is unfortunate when quotas are low. Consequently, rules were tightened in early 1997. It is problematic to designate quotas for polar bear hunting to hunters and fishermen using small boats who already earn their main income from hunting and fishing. Hunting is only practiced as a sole occupation in the outermost districts. In all other areas hunting is inevitably linked with seasonal fishing.

No one has officially defined when a person is considered a hunter and when a person is considered a fisherman. Outsiders find it odd that there is no official definition of a hunter in Greenland, where hunting

remains an important occupation and is the single most important occupation in some areas. KNAPK, the organization of fishermen and hunters, has no official definition of a hunter, even though this lack of definition may in fact be a problem in situations where personal quotas are being negotiated.

No one wants to voluntarily give up the “freedom” of being allowed to catch a polar bear or having a share of the caribou quota, not even if their main occupation is to catch fish from large trawlers year round. At the same time organizations, municipalities and others argue that there are too many commercial hunters.

In the light of this dilemma, the Greenland Home Rule government introduced stricter requirements for obtaining commercial hunting licenses in early 1997. The new requirements are intended to reduce the number of commercial hunters in open-water areas. The effect of these new requirements on the polar bear catch is unknown at this time. No significant changes are expected in East and North Greenland, where the majority of hunters are commercial hunters in the original sense of the term.

Research on Polar Bears in Greenland, Primo 1993 to Primo 1997

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Introduction

Between January 1993 and January 1997, polar bear studies were conducted by the Greenland Institute of Natural Resources (P.O. Box 570, 3900 Nuuk, Greenland, and c/o National Environmental Research Institute, Department of Arctic Environment, Tagensvej 135, 4th floor, DK-2200 Copenhagen). Information about the hunt was collected by the Ministry for Fisheries, Hunting and Agriculture (Nuuk), and by the Greenland Institute of Natural Resources.

For places mentioned in the text *cf.* Figure 1.

Monitoring the Greenland polar bear hunt

In Greenland there are no quotas for the catch of polar bears. Until 1987 information about the number of bears taken was available through the Hunters' Lists of Game (HLG) where hunters reported their catch of wildlife voluntarily. The summaries of the catch, including estimates of catch not reported, were published annually by the Ministry for Greenland-Copenhagen (until 1983). After the Greenland Home Rule Government took over the HLG-system, unpublished summaries of the catch in 1985, 1986 and 1987 became available from the Ministry for Fisheries, Hunting and Agriculture (Nuuk). A new system of reporting catches — the "Piniarneq" (Greenland word for "catch") — was introduced in Greenland on 1 January 1993. The Piniarneq also relies upon each hunter voluntarily reporting his annual catch (between 1 October and 30 September) of various wildlife, including polar bears. The information on catches is compiled by the Ministry for Fishery, Hunting and Agriculture from which published summaries by area are available for 1993 and 1994 (Anon. 1995, 1996), and unpublished for 1995 (Table 1).

The catch reported through the Piniarneq may both be an under-estimate (i.e. some kills not reported) and an over-estimate. To obtain a hunting license for the coming year, a hunter needs to report his catch through the Piniarneq (in practice the catch of all species is reported in a booklet). Inevitably, a hunter may sometimes miss to report a catch of whatever species. Often two or more hunters participate in a polar bear hunt, and the risk therefore exists that they all have reported a particular kill in the Piniarneq giving an over-estimate of

the catch. As far as I am informed it has not been attempted to verify how reliable or representative the catch figures in the Piniarneq summaries are.

From 11 May 1994 it became mandatory to report every kill of a polar bear on specific forms where information on name of the hunter, civil registration number, settlement, place and date of the kill, sex and approximate age had to be given. To be able to reduce the problem of potential double or triple reporting of a single kill the hunter who finishes off the bear is supposed to fill in the form and also give the name etc. of the other participants in the catch. So far only a few filled-in forms have been received by the Ministry for Fishery, Hunting and Agriculture: 17 in 1994 (all from Ittoqqortoormiit/Scoresbysund); in 1995, 53 were received from Ittoqqortoormiit/Scoresbysund, 4 from Tasiilaq/ Ammassalik, 6 from Nanortalik, 2 from Nuuk, and 1 from Upernavik. By early December 1996, 14 were reported from Ittoqqortoormiit/Scoresbysund, 4 from Tasiilaq/ Ammassalik, 1 from Nanortalik, and 3 from Uummannaq. The nearly complete lack of reports from the municipalities of Upernavik and Avanersuaq/Thule is particularly noteworthy. These are the two most important polar bear hunting areas in Northwestern Greenland where an estimated *ca.* 50 polar bears are caught annually (Born 1995, Rosing-Asvid and Born 1995).

To provide more specific information about the Greenland catch of polar bears, the Greenland Institute of Natural Resources has continued its collection of biological samples from the kill (information about the kill, body length and girth, lower premolar 1, sexual organs, and various tissues). Each hunter is paid about 90 US dollars per set of polar bear samples. Between 1993 and 1997, samples from a total of 115 polar bears have been received; of these 107 were collected in the Ittoqqortoormiit/Scoresbysund area, and the remainder in Avanersuaq/Thule.

Laboratory analyses

Results of analyses of contents of various heavy metals (Cd, Hg, Zn, Se) in muscle, liver and kidney tissues from polar bears sampled at Ittoqqortoormiit/Scoresbysund were presented in Dietz *et al.* (1995). Similar information from bears sampled in the Upernavik and Avanersuaq/Thule areas (NW Greenland)

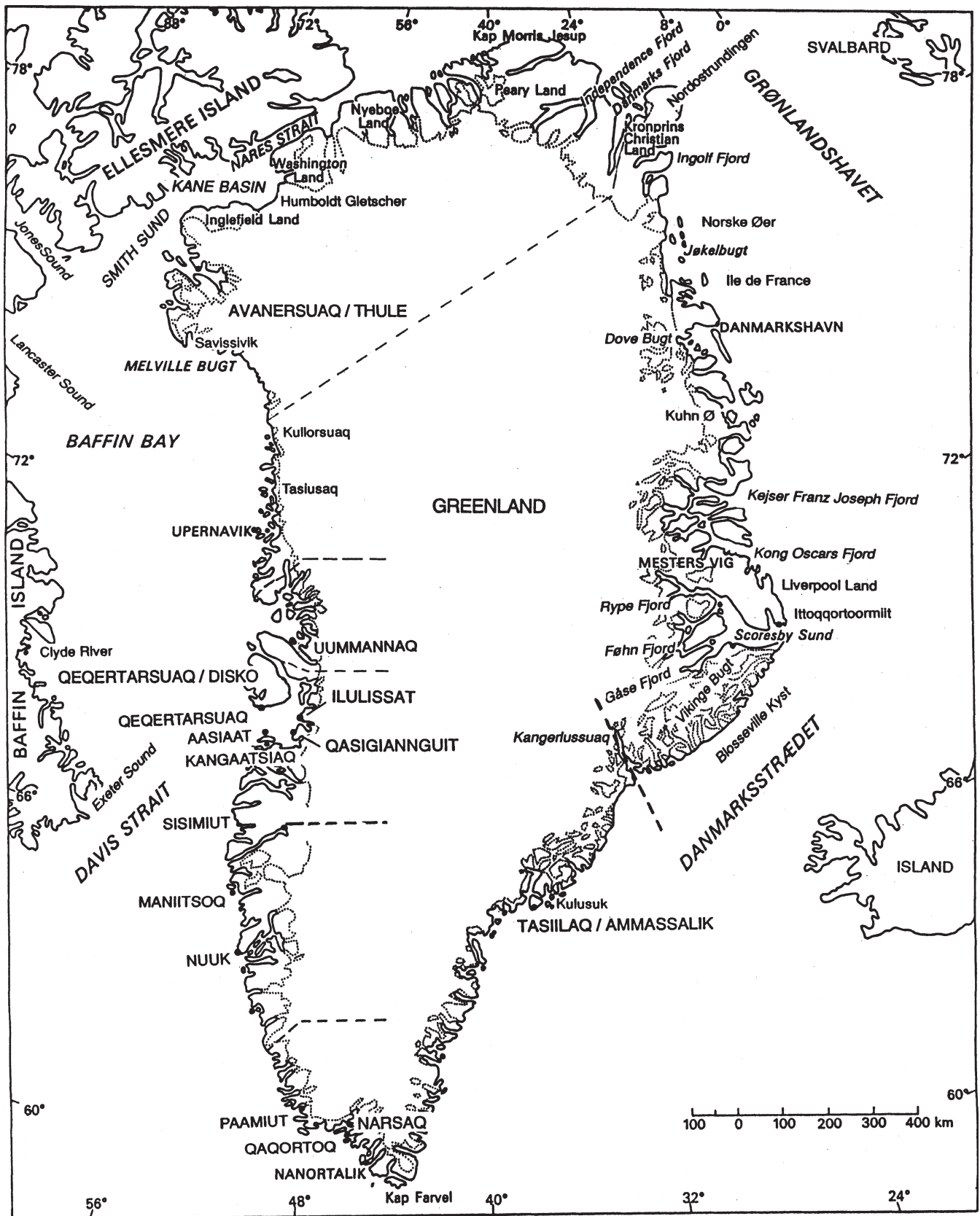


FIG. 1. Map of Greenland with places mentioned in the text. Some municipality borders are shown.

Table 1. The Greenland catch of polar bears (1993–1995) reported in the Piniarneq (see text). Source: Ministry for Fisheries, Hunting and Agriculture (Nuuk) — unpublished.

		<i>Municipality</i>	<i>Year</i>		
			<i>1993</i>	<i>1994</i>	<i>1995</i>
Central W and NW Greenland	Likely taken from the Baffin Bay management unit. However, about 25% reported for Avanersuaq/Thule may have been caught from the Kane Basin management unit. Some of those reported from Kangaatsiaq and Sisimiut may have come from the Davis Strait management unit.	Avanersuaq	21	33	16
		Upernavik	43	25	24
		Uummannaq	3	0	4
		Ilulissat	1	1	2
		Qasigianniguit	0	0	2
		Aasiaat	4	3	1
		Qeqertarsuaq	6	1	0
		Kangaatsiaq	1	2	10
		Sisimiut	0	1	4
			Likely taken from the Davis Strait management unit.	Maniitsoq	4
		Nuuk	0	0	2
SW Greenland	Likely taken from the East Greenland population(s)?	Paamiut	1	2	1
		Narsaq	1	0	0
		Qaqortoq	0	0	2
		Nanortalik	1	0	6
East Greenland		Ammassalik	15	14	22
		Illoqqortoormiit	28	35	20
Total			129	117	121

and in the Ittoqqortoormiit/Scoresbysund area was presented in Dietz *et al.* (1996). Prevalence of infestation with *Trichinella* in polar bears from northwestern and eastern Greenland was presented in Henriksen *et al.* (1993).

Field studies

The Canadian-Greenland study of polar bears in the Baffin Bay and adjacent areas initiated in 1991 has continued. As a part of this study which aims at delineating stocks and determining abundance of polar bears in the Baffin Bay and adjacent areas by use of satellite-telemetry and “mark-recapture”, personnel from the Greenland Institute of Natural Resources in cooperation with the Department of Renewable Resources (Government of the N.W.T.) marked polar bears and fitted adult female bears with radio-collars in the

Melville Bay area during May 1993. With the same purposes personnel from these institutes operated during the spring of 1994, 1995 and 1996 in the Central Canadian High Arctic, along eastern Ellesmere Island and in the Kane Basin region.

Preliminary results have been presented to the Canadian Polar Bear Technical Committee’s meetings in January 1996 and 1997, and to the meeting of the Canada/Greenland Joint Commission on the Conservation and management of Narwhal and Beluga in December 1995. Based on cluster-analyses of medians of telemetered relocations from 79 adult female bears that transmitted for more than a year, three shared stocks (or management units) have tentatively been identified (preliminary numbers): Kane Basin (200 bears), Baffin Bay (2200), and Davis Strait (1200); see also Canadian progress reports to this meeting.

As a part of the international NEW-study in the Northeast Water at NE Greenland, the Greenland Institute of Natural Resources, the Norwegian Polar Institute (Oslo), the Norwegian Institute of Nature Research (Trondheim) and the Zoological Museum (University of Oslo) marked a total of 21 polar bears and fitted eight adult female bears with radio-collars in May 1993 (Born and Thomassen 1994). Based on two years movement of the collared bears it was concluded that a local group of polar bears is found in Northeast Greenland between about 78°N and 81°N, and that the coastal areas of this region is a denning site. However, a male bear marked in 1993 at the NEW was taken by hunters in Scoresby Sund (approximately 70°N) in February 1995, indicating that some exchange does occur with southern areas of eastern Greenland (Born *et al.* 1996).

During the RV “Polarstern”’s (Alfred Wegener Institute, Bremerhaven) expedition to Central East Greenland in August and September 1994, the Norwegian Polar Institute (Oslo), the Zoological Museum (University of Oslo) and the Greenland Institute of Natural Resources marked a total of 7 polar bears and fitted two adult female bears with radio-collars at Traill Ø (about 72° 20’N) (Born and Wiig 1995). These two collars still function (January 1997).

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Status of Polar Bears in Norway 1993–1996

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Management

Svalbard has been a part of Norway since sovereignty of the archipelago was granted by the Svalbard Treaty in 1925. The Governor of Svalbard (Sysselmannen) and staff oversee Norway's rights and duties under the Svalbard Treaty. The Governor's office also has management responsibilities for freshwater-fish and wildlife, pollution and oil spill protection, environmental monitoring, the warden service and urban and commercial development. The Governor's office is also the cultural and environmental protection authority in Svalbard. The Svalbard Treaty applies to all terrestrial areas and up to 4 nautical miles offshore. Beyond this zone, Norway claims an economic zone to continental shelf areas to which Norwegian Law applies. Therefore, under Norwegian Game Law, all game are protected unless otherwise stated. There are disputed areas in the Barents Sea for which jurisdiction is unclear and there has been no resolution of jurisdiction over these areas in the last few years.

Polar bears in Svalbard and adjoining waters under the Svalbard Treaty continue to have complete protection from harvest. Irrespective of the protection regulations or other restrictions on hunting, the Governor (or Head of Station in Jan Mayen) can kill, or give permission to kill, polar bears which remain close to permanent or temporary human settlement and thus entail risk of injury to person or of other substantial damage. Similarly, permission to kill wildlife that is injured or suffering in other ways can be granted by the same authorities.

Use and trade of polar bear products

Between 1985 and 1995, Norway imported 265 hides with 89% from Canada and the remainder from Greenland. There was an export of 96 hides and 9,600 pieces during the same period. There were an additional four export permits for scientific purposes. CITES permits for export and import of polar bear skins and parts of skins in Norway, 1985–1995 are given in Table 1.

Management changes

In autumn 1995, the Norwegian Government presented a White Paper to the Parliament which discussed environmental management on Svalbard. According to this White Paper, one of the primary environmental goals of the Government is to preserve the unique wilderness quality of Svalbard. This goal also applies to the management of Svalbard's fauna. In other words-the animals of Svalbard shall have the opportunity to develop naturally, and should as far as possible be protected from human influence or disturbance.

The Norwegian Parliament supports these goals. In the White Paper, the Government states that in the case of environmental concerns conflicting with other interests, the environmental concerns should be given due weight. The Parliament went further than the government on this issue. In recommendations to the White Paper, the Parliament stated that environmental concerns shall be given first priority if conflicts arise with other interests. These ambitious environmental goals should be taken as a sign of real commitment on the side of both the Norwegian Government and the Parliament concerning protection of Svalbard's natural environment. They indicate that Norway is willing to assume its international responsibilities regarding protection of the Arctic environment. This provides an advantageous starting point for those involved in the day to day management of Svalbard's nature and to secure this unique natural heritage for future generations.

Protected areas are key features in the conservation of the Svalbard wilderness. Approximately 35,000 km² (56%) of Svalbard's 63,000 km² is in protected in National Parks or nature reserves. At the moment preparations are underway to give Bjørnøya, the southernmost island in the Svalbard archipelago, protection as a nature reserve. Furthermore, we have started a process to evaluate the degree of representation of different types of nature that are found in the existing protected areas. This work, which also include an evaluation of the more than 20 years old regulations, is done in cooperation with NP among others. Suggestions about

Table 1. CITES permits for export and import of polar bear skins and parts of skins in Norway, 1985–1995.

<i>Year</i>	<i>Export</i>	<i>Origin</i>	<i>Import (hides)</i>	<i>Origin</i>
1985	0		0	
1986	46 skins	Canada	93	Canada
1987	5 skins	Canada (4) Norway (1)	21	Canada
1988	4 skins	Canada	25	Canada
	3200 pieces	Canada		
1989	6 skins	Canada	14	Canada
	1000 pieces			
1990	7 skins	Canada	28	Canada
	3200 pieces	Canada		
1991	2 skins	Canada	19	Canada (11)
	1000 pieces	Canada		Greenland (8)
1992	7 skins	Canada (3) Greenland (4)	18	Canada (8) Greenland (10)
	700 pieces	Canada		
1993	8 skins	Canada (7) Greenland (1)	8	Canada (7) Greenland (1)
1994	9 skins	Canada	24	Canada (16) Greenland (8)
1995	2 skins	Canada	15	Canada (14)
	100 pieces	Canada		Greenland (1)

protection of new areas with qualities that are sparsely represented in existing protected areas will be promoted. Important polar bear habitats are one of the criteria that will be considered in this process.

Svalbard is a part of Norway and treated similar to areas on the mainland. However, because Norway has sovereignty over these Svalbard through an international treaty, it is somewhat special in a juridical matter (i.e., not all mainland Acts and regulations are applicable to Svalbard). Authority bodies with management responsibility on the mainland, does not automatically have the same responsibility on Svalbard. Up to now the Ministry of Environment has been the Governors closest upper authority. The directorates that are given responsibility in management of environment on the mainland, have not had such authority on Svalbard earlier. The Directorate of nature management and the Norwegian Pollution Control Authority, which are the bodies responsible for environmental management on the mainland, are now also given authority on Svalbard by delegation from the Ministry. We look forward to in

a greater extent than earlier, co-operation with these directorates which represent a huge amount of management experience.

Tourism

Similar to other areas of the arctic, Svalbard is becoming a population tourist destination. Between 1975 to 1994, the number of passengers on cruise ships has increased from 5,000 to 24,000 people per year (1996). The total number of tourists was estimated at 30,000 people in 1994 (*op. cit.*). Similarly, the number of tourist travelling on land is increasing. Between 1992 and 1995, rental of snowscooters increased from 1400 to 3500 days (1996). The Governor of Svalbard has the management authority in Svalbard and is the chief of environmental management and to a large extent tourism is controlled by limited access to protected areas.

Development of tourism as economic life is given political priority on Svalbard. Special regulations with goals and directions for this development have been

determined and began in January 1992. A framework plan for management of tourism and outdoor recreation is a supplement to the regulations. In this plan Svalbard is divided into different management categories with different management strategies. In the most vulnerable areas (i.e. national parks and nature reserves) a low level of activity and only “soft” forms of outdoor recreation are accepted. Use of motorised vehicles are prohibited. Travellers in these areas are obliged to notify the Governor about their travelling plans.

Increasing tourism activities will also imply a potential increase in conflicts between man and polar bears. The Governor's attitude in this case, is that it is the tourist and not the bear that represent a problem. The polar bear was the first inhabitant of the area and have priority to the intruding man. If this human-polar bear problems increase, regulations will primarily be directed against man's activity and not against polar bears.

Problem kills and encounters

Polar bears killed in Svalbard 1993–1996

All polar bear hunting in Norwegian territory has been banned since 1973. After this year polar bears have only been shot in acts of self defence, as precautionary measures or in special cases as acts of mercy. Only bears within settlements represent such a threat that may result in precautionary killing of a polar bear. All such incidents are considered a police matter and are either investigated by, or authorised by, the Governor of Svalbard.

Polar bears that destroy cabins and confrontations between humans and polar bears, are the two most common conflicts handled by the Governor. There are about 250 private cabins on Svalbard. Most of them are found near Longyearbyen, but a significant number are spread around on Spitsbergen. In practice, permission is not given to kill bears that cause damage. For example; in spring 1996, about 50 cabins within a small area and over short time were destroyed by polar bears. This situation was a not sufficient reason for the Governor to grant permission to kill the bears.

Fifteen bears were shot in Svalbard in the four years from 1993 to 1996. Ten cases were self defence, three precautionary measures, and two acts of mercy. Six of the cases of self defence occurred at cabins or tents in the wilderness, two at a research station, one during a visit to an uninhabited island, and one incident occurred just outside of town. Four of the self defence cases involved non-residents (i.e., tourists and scientists) and the other six cases involved local trappers or research station crews. Half of the self defence cases occurred in

March (3) and April (2), while the remaining cases were spread throughout the year. Data on bears killed was obtained from the Governor's files. No charges were laid in any instance.

Eight of the 15 bears killed were adults, five subadults, one was a cub and one unknown. Seven of the ten bears killed in self defence were males, two females and one unknown. Of these four were adults, four subadults, one a cub and one unknown.

In addition to the bears that were shot, two other bears were killed as a result of interactions with humans in the same period. One adult female died as a result of immobilisation in connection with scientific tagging. An oestrous female was killed by an adult male after researchers departed from the tagging site. One cub-of-the-year was killed by a chained dog at Isfjord Radio.

Human casualties

Between 1993 and 1996, there were two human fatalities and one injury in two separate confrontations. On 30 March 1995, two unarmed adult female tourists were attacked by a 88 kg lone yearling while hiking on a mountain just outside the town of Longyearbyen (population approx. 1,200). One woman escaped uninjured while the other was killed. The police later shot the bear. On 1 September 1995, two male tourists were attacked by an adult male bear on a remote island in eastern Svalbard. The two tourists defended themselves with a .22 calibre pistol which proved ineffective. One man was killed, the other injured. Police later shot the bear.

Since 1971, four people have been killed by bears in Svalbard, and five injured. Apart from the two above mentioned cases people were killed in 1971 and 1977, and injuries occurred in 1975, 1978 and 1987 (2).

Population size

No new estimate is available on the population size of polar bears in the Svalbard area. There is no basis to alter the population size and trend estimate provided in Wiig *et al.* (1995).

Population monitoring

Monitoring of the Svalbard population is currently focused on two research studies: reproductive ecology and movements of female polar bears on Hopen Island and toxicology.

To effectively monitor polar bear populations, several population parameters should be followed: adult female survival, female reproductive rates, population

size, and cub survival. Integration of a mark-recapture study and population ecology studies would produce the required results but a large and sustained effort and funding commitment is required. A change in a population is in itself interesting, but without an understanding of the underlying factors causing the change(s), the information is not useful for developing effective conservation strategies. Therefore, an understanding of prey density and distribution, sea ice conditions, and toxic chemical loads are also required with multi-disciplinary co-operation. Currently, existing information is insufficient to effectively monitor the status of the Svalbard polar bear population.

Research

Tables 2 and 3 provide information on number of bears tagged and satellite telemetry effort at Svalbard in the period 1988–1996.

Population borders

Distribution and movements of polar bears (*Ursus maritimus*) in the Svalbard area were studied, using mark and recapture and satellite radio telemetry in the period 1988 to 1994 (Wiig 1995). Thirty-six females were tracked by satellite for more than 330 days. Two bears out of 370 tagged in the period 1966 to 1993 were reported in the Greenland harvest, which have been about 100 per year over the same period. About 95% of tracking days and 89% distance covered were from the Norwegian part of the area, the rest were from Russian territory. Mean minimum polygon home range size

estimates for 36 females, each tracked for more than 330 days, was $69,468 \pm 79,136 \text{ km}^2$. Twenty-five percent (9/36) of the females moved eastwards and spent time in Russian territory. Only two of them (6%), one of bear in two different years, has landed at Franz Josef Land. Information on seasonal fidelity based on locations one or several years after the first tagging exists for 38 female and 4 male bears. For 30 females, the mean distance between locations after one year was $149 \pm 143 \text{ km}$ from the first tagging site. After two years, the mean distance was $79 \pm 82 \text{ km}$ for 15 females, after three years, the distance was $51 \pm 30 \text{ km}$ for nine females and after four years $32 \pm 32 \text{ km}$ for 4 bears. The regression slope between distances and time is significant and negative. Denning locations were obtained from 25 of the females from satellite data. Twenty-four of these were at Svalbard and one (4%) at Franz Josef Land. Satellite data combined with mark recapture data show that the polar bears have a very high degree of seasonal fidelity to Svalbard. It was suggested that the migration of polar bears between Svalbard and Greenland and between Svalbard and Russia is relatively low and that the Svalbard population of polar bears can be managed as a local population.

Additional radio telemetry data is required from north-eastern and north-western Svalbard to delineate the seasonal and annual population boundaries of the population. Research planned for 1997 to satellite collar bears in the eastern Barents Sea will hopefully assist in population delineation.

Table 2. Number of polar bears tagged at Svalbard in 1988–1996. 2–years, 1–years and COYs (cubs-of-the-year) were captured with their mother.

<i>Sex/age</i>	1988	1989	1990	1991	1992	1993	1994	1995	1996	Total
Males	1	—	12	7	8	16	15	18	17	94
Females	4	8	12	19	25	17	9	24	29	147
2–years	—	—	1	2	—	—	—	2	1	3
1–years	2	2	7	2	4	2	1	3	5	28
COYs	—	—	—	—	9	12	7	18	35	81
Total	7	10	32	30	46	47	33	65	87	353

Table 3. Number of days with positions by year for polar bears tracked by satellite telemetry in the Svalbard area. Number of individuals tracked and new pttts by year is also given.

	1988	1989	1990	1991	1992	1993	1994	1995	1996
# positions	43	152	347	545	565	669	609	695	578
# individuals	4	7	13	22	28	27	24	30	25
# deployed	4	6	10	20	29	14	9	15	10
# no data	0	0	0	1	12	0	3	3	2

In contrast to earlier years, females radio collared near Hopen Island in 1996 moved further east than typically seen in other years (Figure 1). The movements suggest greater annual variation in population overlap with bears from Franz Josef Land and Novaya Zemlya than previously thought.

Population dynamics and ecology

Between 1988 and 1993, only one female older than 15 years was caught. Based on data sampled by satellite transmitters on females between 4 and 17 years of age dates for maternity den entry was between 7 September and 12 December and emergence dates were between 2 March and 27 April. Mean denning duration was 153 days (Wiig in press). Reproductive status of females was assessed 115 times. The youngest age of first reproduction was 5 years and mean rate of litter production for females 7–17 years was 0.41 cubs/female/year. Birth success was estimated as the proportion of females available to mate in spring (age = $x-1$). Alone or with two-year-olds that presumably produced a litter the following winter (age = x) based on satellite data for the same range was 0.80. Based on satellite telemetry, cub survival in the first year was 0.55, assuming the mother survived.

Denning areas

Two new areas have been identified as denning habitat in Svalbard: Hopen Island (25°E and 76.5°N) and south-eastern Spitsbergen. The number of dens observed on Hopen Island was 7 in 1994, 19 in 1995, and 35 in 1996 but search effort has increased each year. South-eastern Spitsbergen was revealed as a denning area, less dense than other Svalbard areas, largely through satellite telemetry.

Impacts of toxic chemicals on polar bears

The main objective of this research is to investigate how environmental pollutants (i.e., organochlorines, radionuclides, and heavy metals) affect reproduction and cub survival in polar bears.

A comprehensive survey of organochlorine (OC) contaminants in polar bears has been conducted in subcutaneous fat samples, blood, and milk (Bernhoft *et al.* 1997). As earlier research has suggested, the PCB levels in polar bears at Svalbard are extremely high and accumulate with age in adult males. Results indicate that there is more efficient transfer of OC between lipid depots and blood than from the blood to milk. OC pattern in nursing yearlings indicates a low transfer of the highest chlorinated PCBs into maternal milk but other

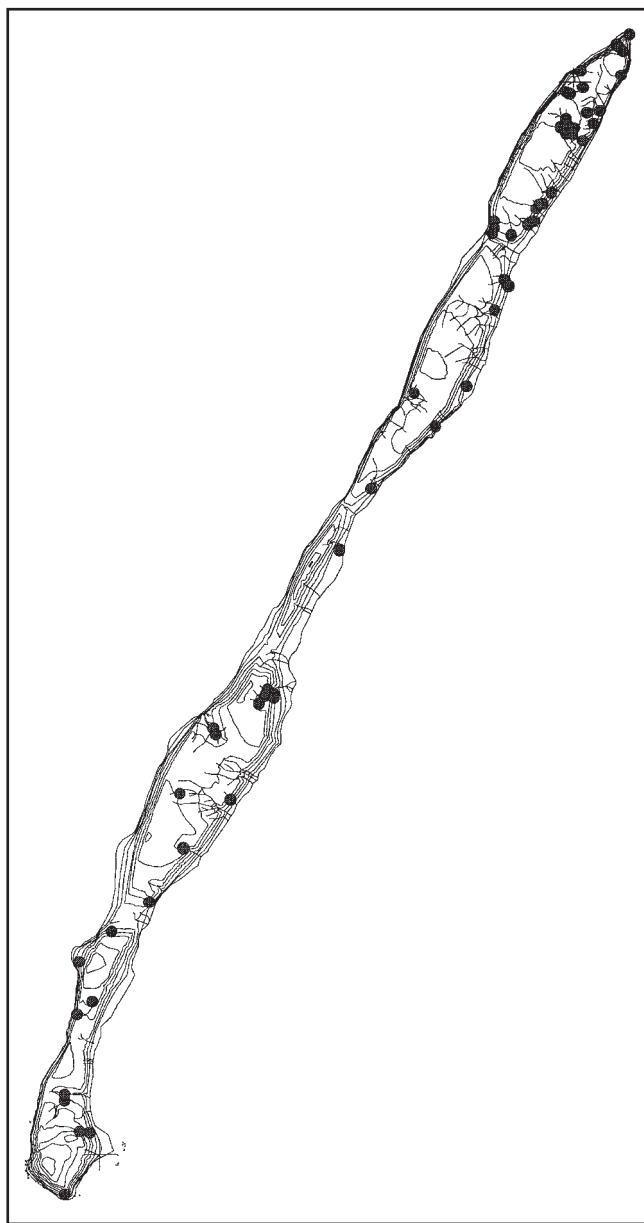


FIG. 1. Maternity den locations on Hopen Island, SE Svalbard in 1994, 1995, and 1996 (1cm = 2km).

OCs are higher in the lipid depots of yearlings than their mothers.

The project will continue to monitor the levels of organochlorines, radionuclides, and heavy metals in polar bears from sampling areas near Svalbard and the Barents Sea. To examine the ecological impacts of environmental toxins, we will monitor survival of polar bear cubs using radio telemetry and sightings. Hopefully, we will be able to relate cub survival to environmental pollutant load of the mother and the cub. We hope to assess the relationship between reproductive parameters, particularly reproductive failure) of adult female polar

bears and environmental pollutant load. Assess physiological responses to environmental pollutants (e.g., hormone titres, vitamin A concentrations, immune response, growth rates, and developmental defects). We will also attempt to link pollutant load and signature relative to habitat use and movement patterns of radio collared female polar bears.

Associated research on large scale toxin transfer (oceanic and atmospheric) and on transfer of toxins through the food chain are being conducted.

Ongoing research

Population estimation

An assessment of the importance of determining the polar bear population size in the Svalbard area relative to other management objectives has yet to be completed. The population is not harvested and therefore, the need for an accurate population estimate may be less critical than for harvested populations. Assessment of population estimates for monitoring population health has not been conducted.

If population size is to be estimated, two options are possible: mark-recapture and aerial survey. For mark-recapture studies, critical factors in obtaining an accurate estimate are sample size, random sampling, and appropriate delineation of the study population. Assessing the required mark-recapture sample size for the Svalbard population is difficult as the population may be anywhere from 1,700–6,700 bears; the population size being dependent upon an *a priori* definition which will be based on satellite telemetry data. Based

on simulations conducted using POPAN4 (Arnason and Baniuk 1980, Arnason *et al* 1995) it was recommended that 200–300 independent bears (2 years of age) be captured in any given year (Table 4) (Deracher 1996). It was concluded that the study should sample for five years to provide 3–4 estimates of population size. Additional satellite telemetry data on females is required from the north and western areas of Svalbard to better delineate the study population.

Aerial survey techniques have been contemplated for use to estimate the size of polar bear populations but only pilot studies have been conducted to date. It is possible that an aerial survey could be conducted over the sea ice but the option presents greater risk given that methodology has not been tested and the approach is highly dependent upon weather conditions in the survey year.

Overall, a mark-recapture study is likely the best approach (maximum information return and lowest risk) to estimating the polar bear population in Svalbard if sufficient funding and logistics are available to meet the required sample sizes. Collection of information on age-structure, reproductive rates, growth rates, condition, and sampling for environmental pollutants are compatible with mark-recapture studies but are not possible with aerial surveys. However, aerial surveys would yield a population estimate at a lower cost and sooner than multi-year mark-recapture studies.

Pending additional funding to conduct a population census; field research to estimate population size will begin in 1998.

Table 4. Expected confidence intervals based on a hypothetical population size (constant), annual sample size, and five years of sampling. Estimates are based on pooling sexes (50:50 sex ratio) and age class with a mean survival rate of 0.92 and five years of sampling. All mark-recapture model assumptions are assumed to have been met. Estimates are derived from the program Simulate in POPAN4 (Arnason *et al.* 1995).

<i>Hypothetical population size</i>	<i>Probability of capture</i>	<i>Annual sample size</i>	<i>95% confidence interval of N</i>
2000	0.05	100	0–4288
2000	0.10	200	953–3047
2000	0.15	300	1353–2647
2000	0.20	400	1554–2446
5000	0.04	200	33–9967
5000	0.06	300	2190–7810
5000	0.08	400	2862–7138
5000	0.10	500	3412–6588

Ageing

A pilot study on application of new methodology to ageing polar bears is being conducted in co-operation with Havforskning Institute in Bergen. Decalcified and thin-sectioned teeth are scanned into a computerised image. In theory, annulations can be counted using density shifts; similar to annular rings on fish otoliths.

Climate change

Hopen Island has been selected as a long-term monitoring site for polar bears in the Svalbard Archipelago. This project will involve radio tagging of female polar bears from Hopen Island to monitor movements, reproductive patterns, and denning use. The goal of this study is to provide baseline information as part of a long-term monitoring program of climatic variation or change. This project is linked to research on habitat use patterns. Understanding the impacts of variation in sea ice on polar bears will provide the background necessary to predict and assess the potential impacts of human induced climate change. A primary objective is to integrate a sea ice distribution model with various climate change scenarios and link these to a model of polar bear energetics.

Marine ecology

Current understanding of the interactions of polar bears, seals and sea ice in the pack-ice of the Barents Sea is rudimentary. It is thought that ringed, bearded and in particular, harp seals play a role in the ecology of polar bears in the marginal ice zone. We seek to understand the relative contribution of each species to the diet of bears in the Barents Sea and Svalbard area. A Norwegian Polar Institute multi-disciplined research program aimed at integration of biological and physical sciences is to begin in 1998. Polar bears, seals, and sea birds will dominate the research priorities with support from physical oceanographers and research on lower trophic levels.

Habitat use

The primary objective of this study is to investigate seasonal habitat use patterns of adult female polar bears in the shifting pack ice of the Barents Sea. We hope to link variation in sea ice distribution and characteristics with habitat use and movement patterns. We also seek an understanding of how polar bears move relative to sudden shifts in sea ice distribution within a season. Annual variation in habitat use patterns will be examined relative to the condition of adult females. We hope to determine the relationship between the sea ice distribution in autumn and the number of females denning on

Hopen Island and examine the relationship between variation in the reproductive parameters and habitat use (inter-birth interval, cub survival, age-specific litter size) of female polar bears.

We intend to describe habitats used by satellite radio collared polar bears and relate this to sea ice characteristics and dynamics. In 1998 and 1999, we hope to conduct aerial surveys of seals, sea ice and polar bears during the spring to further refine habitat use patterns.

Toxicology

The main objective of this research is to investigate how environmental pollutants (i.e., organochlorines, radionuclides, and heavy metals) affect reproduction and cub survival in polar bears. The project will continue to monitor the levels of organochlorines, radionuclides, and heavy metals in polar bears from sampling areas near Svalbard and the Barents Sea. To examine the ecological impacts of environmental toxins, we will monitor the survival of polar bear cubs using radio telemetry and sightings. Hopefully, we will be able to relate cub survival to environmental pollutant load of the mother and the cub. We hope to assess the relationship between reproductive parameters, particularly reproductive failure) of adult female polar bears and environmental pollutant load. Assess physiological responses to environmental pollutants (e.g., hormone titres, vitamin A concentrations, immune response, growth rates, and developmental defects). We will also attempt to link pollutant load and signature relative to habitat use and movement patterns of radio collared female polar bears.

Associated research on large scale toxin transfer (oceanic and atmospheric) and on transfer of toxins through the food chain are being conducted.

Co-operative research with Russia and USA

Population studies

In spring 1995, 20 female polar bears were instrumented with satellite transmitters in the western Russian Arctic. The objective is to study the population borders in western Russia. The fieldwork was funded by USA. For provisional results see the American report this meeting.

Funding has been secured for a co-operative research program between Norway and Russian scientists to study polar bears in the eastern Barents Sea (east of 35°E). Research objectives include deployment of 12–15 satellite radio collars to assist with population

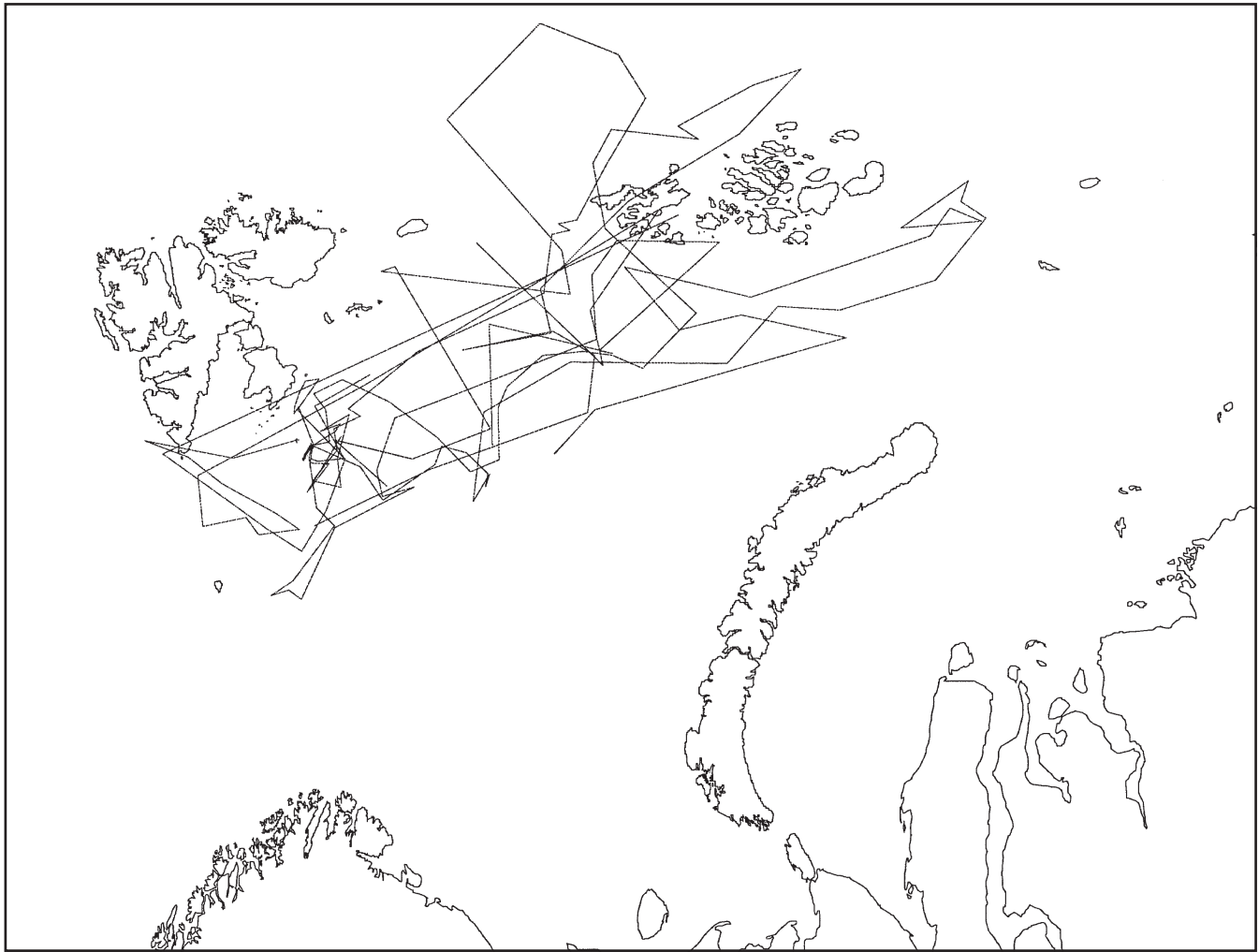


FIG. 2. Movements of eight adult female polar bears, radio-collared near Hopen Island, between April 1996–January 1997.

Table 5. ESR dose levels, activity, beta and alpha level measured from polar bear enamel at Svalbard.

<i>Age (years)</i>	<i>ESR-dose (Gy)</i>	<i>Activity (Bq/g)*</i>	<i>beta</i>	<i>alpha</i>
4–5	0.156	0.140	0.05	0.06
4	0.124	0.108	0.29	0.14
3–4	0.082	0.066	0.24	0.11
6–7	0.196	0.180	0.30	0.17
4–5	0.115	0.099	0.14	0.08
2–3	0.139	0.123	0.21	0.10
6–7	0.144	0.128	0.18	0.08
5	0.157	0.141	0.31	0.14
5	0.266	0.250	0.16	0.09
2	0.113	0.097	0.53	0.18

* After correction on a maximum possible dose obtained during storing.

delineation and habitat use. In addition, materials for toxic chemical research, fatty acid profiles (diet studies), and carbon-nitrogen based trophic level studies will be collected.

Radionuclides

A pilot study of ESR-assessment of dose of radiation accumulated by polar bear from Svalbard were conducted in co-operation with G.A. Klevezal (Institute of Developmental biology, Russia), V.A. Serezhenkov (Institute of Chemical Physics, Russia), and A.E. Bakhur (Institute of Mineral Resources, Russia). The third molar and two premolars (including the vestigial one) from 10 bears killed in Svalbard in 1967–1968 stored at the Zoological Museum in Oslo.

Electron spin resonance (ESR) spectrometry was used to measure the accumulated radiation dose due to the existence of the long lived radiation centres in tooth enamel. The dose of 0.03 Gy is the lowest detectable. The estimate error does not exceed 20%. A method of assessment of the activity of radionuclides in small (100–180 mg) samples was developed. Errors of beta- and alpha-activity estimates are 20% and 30%, respectively.

Mean annual dose of radiation accumulated by polar bear when they were alive was 32.6 mGy (0.0326 Gy) that is ten times as high as the background level of radiation (3 mSv/year) accepted today. Internal radiation during storage could not explain more than 0.016 Gy.

No significant correlation either between ESR-doses and age ($r = 0.49$, $P > 0.05$) or between ESR-dose and activities of beta- or alpha-emitters ($r = -0.25$ and $r = -0.09$, respectively, $P > 0.05$) was found. Lack of correlation between ESR-estimates and activities of incorporated radionuclides suggests irradiation in a short time span. If this irradiation were natural or chronic artificial source, we would see a significant correlation of accumulated dose with age.

Insufficient sample sizes preclude conclusive results but if the same estimates are received on from a more representative sample, it would indicate that doses revealed by ESR-analysis of enamel result from external irregular artificial irradiation.

Plans are to increase sample sizes and improve methodology as funding permits.

Co-operative research with Greenland

In May 1993, eight adult females were instrumented with satellite transmitters in northeast Greenland (Born

et al. 1996). The females showed a high degree of fidelity to the tagging area (See Greenland report this meeting). In September 1994, two additional females were instrumented in the area. Also these showed a local movement pattern.

Miscellaneous

During field research in spring 1996, two female polar bear siblings accompanied by their 11 year-old mother were captured in Svalbard. During field examinations, the two siblings were both noted to have abnormal external genitalia. Photographs examined by Marc Cattet (University of Saskatchewan), and he concurred that the two females were either pseudo-hermaphrodites or hermaphrodites. Causes of the abnormal development are unknown but possible causes are: a natural but rare event known as freemartin effect considered unlikely given the absence of a male sibling, occurrence of excessive maternal androgens, likely from a tumour, or a consequence of toxic substances. Samples collected from the bears are undergoing toxicological analyses and genetic sex determination of the siblings is being conducted.

Associated research on ringed and bearded seals

Research on ringed and bearded seals is ongoing in the Svalbard area co-ordinated by the Norwegian Polar Institute. Studies are being or have been conducted on reproductive ecology, population structure, toxicology, physiology, diving patterns, lactation patterns, and movements monitored by satellite radios.

Population ecology of ringed and bearded seals in the pack ice and marginal ice zone are largely unknown and will become a priority research issue in the coming years.

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Research and Management of Polar Bear Populations in the Russian Arctic 1993–1995

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Research

In 1993–1995, polar bear research in Russia was ongoing under the Russian-American environmental agreement. The American side was represented by scientists from the US National Biological Survey, and the Russian side by specialists from All-Russian Research Institute for Nature Protection of the Russian Ministry of Environmental Protection and Natural Resources (since autumn 1996-State Committee of Russian Federation for Environmental Protection).

Joint Russian-American research on the polar bears in the Russian Arctic was initiated in 1990. Until 1993 it was focused primarily on Wrangel Island and the northern coast of the Chukotka Peninsula and in 1991 the work was conducted in the area of the Severnaya Zemlya archipelago (Belikov *et al.* 1995). In spring 1993 research was started in the south-western part of the East Siberian Sea, and later continued on Wrangel Island. In spring 1994 field work was conducted in the area of the Severnaya Zemlya archipelago and the Taimyr Peninsula, and in 1995 in the vicinity of the northern part of Novaya Zemlya and in the area of Franz Josef Land. Some results of this work are published or in press (Garner *et al.* 1994, Belikov *et al.* 1996).

At present, satellite telemetry data are integrated with Russian satellite images to study the connection of polar bears with different sea ice habitats. This project is being carried out by the National Biological Survey (US) and the Research Institute for Problems of Ecology and Evolution (Russia).

In 1993–1995 the Wrangel Island natural reserve continued their annual polar bear den surveys (see M.S. Stishov this proceedings). During a working meeting of Russian and American specialists in Anchorage 2–3 December, 1996 a thorough analysis of survey methods applied for that work was done. Some gaps and insufficiencies in methodology were pointed at. The suggestions will be taken into consideration when methods are designed for den surveys on Wrangel and Herald Islands and on the northern coast of Russian Northeast in the near future.

Specialists from the Arctic and Antarctic Research Institute and from All-Russian Research Institute for Nature Protection have continued processing data on marine mammal and polar bear observations provided by multi-year aerial ice patrols and by the “Severniiy Polus” drift stations. Results of this work will be presented in the working papers of the International Northern Sea Route Program (INSROP).

In 1995 an American-Russian-Norwegian project on the study and monitoring of bio-accumulation and transfer of radioactive pollutants in marine ecosystems near Alaska, in the Barents Sea and in the western portion of the Kara Sea was begun. The polar bear and walrus were chosen as biological indicators due to their upper position in the pelagic and benthos food chains. Teeth, blood, fat and muscle samples from these species will be collected for the analyses. The American side in the project is represented by the US National Biological Survey, the Russian side by the Research Institute for Problems of Ecology and Evolution and the All-Russian Research Institute for Nature Protection, and the Norwegian side by the Norwegian Polar Institute and Zoological Museum, University of Oslo.

In 1995, the level of accumulated radionuclides in samples of tooth enamel from 10 polar bear skulls collected on Svalbard in 1967–1968 was analysed at the Research Institute for Problems of Ecology and Development. Further activity on this project has been temporally postponed due to lack of funding.

Management

The main body responsible for polar bear management in Russia is the Biological Resources Protection Administration of the State Committee of Russian Federation for Environmental Protection and its regional departments. The federal law “On Animal World” acts as a legislative base for polar bear management and protection in Russia. The polar bear is still listed in the Red Data Book of the Russian Federation and hunting of polar bears is strictly prohibited throughout the Russian Arctic. The only legal type of hunting polar bears is trapping a limited number of cubs for zoos and circuses; this was not done in 1993–1995. As in previous years,

poaching is one of the most serious threats of the polar bear in Russia, particularly in the Russian Northeast. The number of polar bears poached annually has not been estimated.

Due to the varying status of polar bear populations inhabiting the Russian Arctic, various approaches to their protection and management are required. Because of that, in 1995 the All-Russian Research Institute for Nature Protection prepared and forwarded proposals to the Russian State Committee for Environmental Protection modifying the status of the various populations in the second issue of the Red Data Book of the Russian Federation. It is proposed that the polar bear population inhabiting the Barents Sea and part of the Kara Sea be designated Category IV (the population is healthy but its habitat is disturbed); the population of the eastern part of the Kara Sea, the Laptev Sea and the western part of the East Siberian Sea-as Category III (stable but not numerous); the population inhabiting the eastern part of the East Siberian Sea, Chukchi Sea, and the northern part of the Bering Sea-as Category V (restored stable population).

The Chukchi-Alaskan polar bear population is shared by the United States and Russia. In 1992 the countries initiated development of co-ordinated approaches to protection and management of the population. Such approaches have been developed during a number of meetings on the federal level and between representatives of native peoples of Chukotka and Alaska. The parties have agreed to prepare drafts of the Russian-American intergovernmental and intertribal agreements on the protection and management of the Chukchi-Alaskan polar bear population. At the present time these agreements are nearing completion.

Future research

In 1997 a joint Norwegian-Russian research program on polar bear ecology in the eastern Barents Sea and Kara Sea will be started. Polar bears will be captured in Russian waters and satellite radio collars deployed on some adult females. In addition, blood, hair milk and fat biopsies for toxic chemical analysis would be collected from all bears caught.

A joint Russian-American research project on polar bear ecology is planned for 1998. Similar to 1990–1992, future research is to focus on Wrangel and Herald Islands area. Special attention will be paid to surveys of maternity dens.

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Summary of Polar Bear Management in Alaska

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Marine Mammal Protection Act 1994 amendments

The Marine Mammal Protection Act (MMPA) of 1972 provided the framework for U.S. Fish and Wildlife Service (FWS) conservation management activities pertaining to polar bears in Alaska. The MMPA's moratorium on take of marine mammals exception for Alaska Natives has remained unchanged although a mandatory marking, tagging, and reporting requirement to document the polar bear harvest was enacted in 1988, and continues. The MMPA has been reauthorized numerous times since passage in 1972, the most recent occurring in April 1994. Amendments pertaining to polar bear conservation enacted in 1994 are described below.

Importation of polar bear trophies

The 1994 amendments allowed U.S. hunters to import polar bear hides and parts (other than internal organs) taken in hunts in Canada. The Office of Management Authority (OMA) developed draft and final regulations to implement this amendment. These regulations established application requirements, permit procedures, issuance criteria, and permit conditions which were published in the Federal Register on January 3, 1995. A supplemental proposed rule to present the legal and scientific findings required under MMPA section 104(c)(5)(A) was published July 17, 1995 in the Federal Register. The proposed rule was open for comments until August 31, 1995 with a 15 day extension until September 15, 1995. The final regulations were published (following the PBSG) on February 18, 1997, and became effective March 20, 1997. The regulations made the following general determinations and findings: Canada has a monitored and enforced sport-hunting program that is consistent with the International Agreement; Canada has a sport-hunting program based on scientifically sound quotas ensuring the maintenance of the affected population stock at a sustainable level (5 populations approved and 7 populations deferred); the

export from Canada and subsequent import into the United States are consistent with the provisions of the Convention on International Trade in Endangered Species (CITES) and; the export and subsequent import are not likely to contribute to the illegal trade in bear parts. Hides from approved populations taken in the past by U.S. hunters (grandfather provision) may also be imported under a permit.

Cultural exchange-import/export language

The moratorium and exceptions section (Section 101 (a)(6)(A)) was amended to allow a marine mammal product to be imported into the U.S. if: the product was legally possessed and exported by any citizen of the U.S. in conjunction with travel outside the U.S., provided that the product is imported into the U.S. by the same person upon the termination of travel; was acquired outside the U.S. as part of a cultural exchange by an Indian, Aleut, or Eskimo residing in Alaska; or is owned by a Native inhabitant of Russia, Canada, or Greenland and is imported for noncommercial purposes in conjunction with travel within the U.S. or as part of a cultural exchange with an Indian, Aleut, or Eskimo residing in Alaska.

Stock assessments

The 1994 Amendments to the MMPA required the FWS and the National Marine Fisheries Service to develop stock assessment reports for all marine mammal stocks in waters under the jurisdiction of the United States in order to assess the effect of incidental take of marine mammals in commercial fisheries. These stock assessments include information on how stocks were defined, a calculation of Potential Biological Removals (PBRs), and an assessment of whether incidental fishery takes are "insignificant and approaching zero mortality and serious injury rate". The status of both stocks was determined to be "non-strategic." Stock assessments will be updated in future years as additional information becomes available.

Table 1. Number of harvested polar bears, by sex, from the Southern Beaufort Sea 1988–1993. M = Males, F = Females, U = Unknown.

Village	1988/1989 ^a			1989/1990			1990/1991			1991/1992			1992/1993			1993/1994			1994/1995			1995/1996			Total		
	M	F	U	M	F	U	M	F	U	M	F	U	M	F	U	M	F	U	M	F	U	M	F	U	M	F	U
Atqasuk	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	2	1	—
Barrow	20	1	9	10	4	—	10	3	—	14	9	—	17	7	2	20	4	2	5	4	—	11	2	1	107	35	14
Kaktovik	5	2	3	—	1	1	—	—	2	—	—	1	3	—	1	2	3	—	1	—	—	—	1	—	11	7	7
Nuiqsut	2	—	—	—	—	—	—	—	—	—	1	1	—	—	—	2	2	1	—	1	—	1	—	—	5	4	2
Wainwright	9	2	4	6	—	1	4	2	—	2	3	—	3	2	2	7	2	1	3	2	1	5	—	8	39	13	17
Subtotal	37	6	16	16	5	2	14	5	2	16	13	2	23	9	5	32	11	4	9	7	1	17	3	9	164	60	40
Total	59			23			21			31			37			47			17			29			264		

Table 2. Number of polar bears killed by village by harvest year* by sex.

Village	1992/93			1993/94			1994/95			1995/96			Total		
	M	F	U	M	F	U	M	F	U	M	F	U	M	F	U
Ageklekak**	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—
Atqasuk**	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—
Barrow**	17	7	2	20	4	2	5	4	—	11	2	1	53	17	5
L. Diomede	4	2	—	5	3	—	7	3	—	—	—	—	16	8	—
Gambell	3	1	—	14	13	1	1	8	—	—	—	—	18	22	1
Kaktovik**	3	—	—	2	3	—	1	—	—	—	1	—	6	4	—
Kivalina	1	—	—	1	—	—	1	1	—	—	—	—	3	1	—
Nome	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—
Nuiqsut**	—	—	—	2	2	1	—	1	—	1	—	—	3	3	1
Point Hope	9	6	1	3	4	1	15	2	1	1	1	3	28	13	6
Point Lay	2	—	—	—	1	—	1	—	—	—	1	—	3	2	—
Savoonga	—	—	—	7	15	1	8	2	—	—	—	—	15	17	1
Shishmaref	3	—	1	4	—	1	11	4	1	1	1	—	19	5	3
Wainwright**	4	1	2	7	2	1	3	2	1	5	—	8	19	5	12
Wales	4	—	—	—	1	—	2	—	—	—	—	—	6	1	—
Subtotal	50	17	6	67	48	8	56	27	3	19	6	12	192	98	29
Annual Total	73			123			86			37			319		

* Harvest year is from July 1 to June 30.

** Villages harvesting polar bears from the Beaufort Sea stock.

Marine Mammal Cooperative Agreements in Alaska

Section 119 of the 1994 Amendments to MMPA directs: (a) “The Secretary to enter into cooperative agreements with Alaska Native Organizations to conserve marine mammals and provide co-management of subsistence use by Alaska Natives”; (b) “(1) allows for grants to collect and analyze data on marine mammal populations, (2) monitor the harvest ... for subsistence use, (3) participate in marine mammal research . . . , and (4) develop marine mammal co-management structures with federal and State agencies”; (c) outlines the political, legal, governmental or jurisdictional limitations; and (d) authorizes funds to be appropriated. Funds were made available in 1997 for the first time.

North Slope Borough/Inuvialuit Game Council Hunters Agreement

The local user group agreement for conservation of the Southern Beaufort Sea polar bear population between the Inupiat and Inuvialuit Native people of Alaska and the Northwest Territories of Canada was signed in 1988 (NSB/IGC Agreement). It was modeled after the 1973 Agreement and established harvest guidelines among other provisions. The guidelines were based upon scientific data which consider population size, sustainable yield estimates, and the sex ratio of the harvest. The agreement requires the endorsement of Alaska Native hunters while harvest regulations are in place in Canada.

The annual sustainable harvest guidelines were initially established at 76 bears per year and later modified to 77 bears: 38 bears for Alaska and 39 bears for Canada for the southern Beaufort Sea. The total Alaska harvest by Alaska villages party to the agreement from July 1988 to June 1996 was 264 animals or an average of 33 bears per year (Table 1). Annual fluctuations are noted (range: 17–59). The sex ratio of the harvest from 1988–96 was 73:27, males to females. Complete information on the age and sex of harvested bears was available for 66% of the kill. The net mean removal of females (10.0) for this period was below the sustainable yield calculation (12.6) which was based upon a 2:1 male to females sex ratio. The harvest age class composition during 1988 to 1995 was 12.6% cubs, 36.9% sub-adults, and 50.5% adults. Statewide harvests occurred in all months, and the harvest in the Beaufort Sea area was bimodal and favored October to December (52.3%) and April to May (21.7%).

Alaska Nanuuq Commission

The Alaska Nanuuq (polar bear) Commission, was formed on June 16, 1994 of representatives from 14 villages from northern and western coastal Alaska. The Alaska Nanuuq Commission management emphasis will be related to the U.S. Russian Bilateral Agreement, the Alaska/Chukotka Native-to-Native Agreement, a polar bear contaminant project, and the importation of polar bear skins from Canada into the United States.

The Commission contributed to developing and distributing a polar bear-human safety poster along with the North Slope Borough, the Native Village of Barrow, Alaska Department of Fish and Game, U.S. Biological Service, and the FWS.

Other amendments

The 1994 Amendments also added section 101c to the MMPA, which allows the taking of a marine mammal if such taking is imminently necessary for self defense or to save the life of a person in immediate danger. Any taking must be reported to the Secretary of the Interior within 48 hours.

International activities

The following section describes both a domestic and international review of the effectiveness and implementation of the 1973 Agreement. Consultation concerning cooperative research and management programs for the conservation of polar bears in Alaska and Russia are also discussed.

Review of the 1973 Agreement on the Conservation of Polar Bears (1973 Agreement)

Domestic review

In 1995 the United States conducted a review of the United States implementation of the Agreement, as set forth in the 1994 Amendments of the MMPA. Two public meetings were held in June and August, 1995. A draft agency report was transmitted to Washington D.C. on October 10, 1996. This report to Congress identifies four areas of inconsistency between domestic legislation (MMPA) and the 1973 Agreement: (1) the MMPA’s authorization of incidental take of marine mammals; (2) indirect versus more direct implementation of habitat protection measures; (3) use of aircraft to take polar bears; and (4) the MMPA allowance for the take of females with cubs or their cubs and bears entering or in denning areas. A 1993 report by Donald C. Baur, under contract with the Marine Mammal

Commission, entitled “Reconciling the Legal Mechanisms to Protect and Manage Polar Bears under United States Laws and the Agreement for the Conservation of Polar Bears” provided much of the background information for discussions during the review process. The Baur report provides an exhaustive legal review of the subject.

International review

The 1994 MMPA Amendments also require the Secretary of the Interior to consult with the contracting parties that signed the 1973 Agreement to review the effectiveness of each countries’ implementation and establish a process for future reviews. Letters to the respective ministries or Directors of the parties to the Agreement are in preparation. The U.S. requests an evaluation by the parties of their implementation. Opinion of the process for conducting future reviews is also sought.

U.S./Russia Bilateral Agreement

Background

Consistent with the 1973 Agreement and the MMPA, the United States and Russia are proposing to develop a bilateral treaty for the conservation of the shared polar bear population in the Chukchi/Bering seas. Presently management of this shared population occurs independently by each country. Following the dissolution of the U.S.S.R., illegal, unregulated hunting in Russia’s eastern territories has resulted from the increasing economic pressures. Therefore, there is a concern that the continued illegal take or the potential opening of lawful harvest seasons in Russia, combined with the legal harvest in Alaska, could depress the Alaska-Chukotka population in the absence of a science-based coordinated management program involving Alaska and Chukotka Native user support and implementation and law enforcement program. Numerous discussions between the U.S. and Russia occurred from 1993–1997.

A final Environmental Assessment became effective April 21, 1997. The preferred alternative provides the basis for developing a unified and comprehensive management program which includes provisions for regulation of take (quotas), enhanced bio-monitoring and research opportunities, increased habitat protection, and non-consumptive as well as consumptive uses. Oversight of the implementation is proposed through a joint commission of government and native representatives from each country. U.S. Department of State authority to negotiate is required.

Harvest activities

Harvest summary

An exemption in the MMPA on the prohibition of take allows polar bears to be harvested for subsistence purposes or for creating items of handicraft or clothing by coastal dwelling Natives, provided the population(s) is not depleted, and the taking is not wasteful. The Native subsistence harvest includes kills at hunting camps or within villages which may be more appropriately considered defense kills. All other types of harvest are prohibited.

The total Alaska harvest of polar bears from July 1992 to June 1996 was 319 animals with a mean of 80 animals per year. Great annual fluctuations are noted (range: 37–123) (Table 2). No other human caused removals from the population were documented. A general downward trend in harvest statewide was observed when comparing harvest rates from the 1980 to 1990 period ($\bar{x} = 131$) and the 1991 to 1996 period ($\bar{x} = 77$). Declines in the harvest from the Chukchi/Bering seas stock have been primarily responsible for the declines in mean annual harvest. The demographics of Native hunters and their changing desire to harvest polar bears may be in part responsible for the reduced harvest. The availability of polar bears to Native hunters as determined by weather, ice conditions, and bear distribution may also

Table 3. Sex ratio of males to females polar bear harvest, 1990–1996.

	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	Total
All Alaska	80:20 (74)*	63:37 (63)	75:25 (67)	58:42 (115)	67:33 (83)	76:24 (25)	68:32 (427)
Beaufort Sea	74:26 (19)	57:43 (30)	75:25 (32)	74:26 (43)	56:44 (16)	85:15 (20)	71:29 (160)
Chukchi Sea	82:18 (55)	70:30 (33)	75:25 (35)	49:51 (72)	70:30 (67)	40:60 (5)	67:33 (267)

* Number of sexed harvested bears in parentheses.

Table 4. Age class of polar bears harvested in Alaska, 1990/91–1994/5.

	1990/91	1991/92	1992/93	1993/94	1994/95	Total
Cubs	4	2	3	16	10	35
(%)	(8.0)	(6.1)	(8.3)	(17.4)	(16.1)	(12.8)
Subadults	10	5	10	33	28	86
(%)	(20.0)	(15.2)	(27.8)	(35.9)	(45.2)	(31.5)
Adults	36	26	23	43	24	152
(%)	(72.0)	(78.8)	(63.9)	(46.7)	(38.7)	(55.7)
Total	50	33	36	92	62	273

Cubs = 3rd year of life, harvested before May.

Subadults = 3–5 year olds.

Adults = 6 years or greater.

Table 5. Mean age by sex of polar bears harvested in Alaska 1990/91–94/95 (n = number of known/age bears, \bar{x} = mean age, SD = standard deviation).

	1990/91			1991/92			1992/93			1993/94			1994/95		
	n	\bar{x}	SD	n	\bar{x}	SD	n	\bar{x}	SD	n	\bar{x}	SD	n	\bar{x}	SD
Southern Beaufort Sea															
Male	(10)	8.3	8.0	(5)	11.4	10.4	(6)	6.2	5.1	(21)	5.5	5.8	(4)	7.0	10.7
Female	(2)	10.0	8.5	(5)	8.0	2.8	(4)	9.5	—	(6)	7.5	8.5	(2)	3.5	2.1
Unknown	(0)	—	—	(0)	—	—	(0)	—	—	(0)	—	—	(1)	3.0	—
Chukchi Sea															
Male	(32)	11.9	7.1	(17)	11.9	6.7	(17)	10.5	7.0	(31)	8.5	8.2	(36)	6.5	6.0
Female	(6)	11.2	10.7	(6)	9.5	5.5	(8)	10.5	7.5	(32)	6.5	4.9	(19)	7.1	6.9
Unknown	(0)	—	—	(0)	—	—	(1)	3.0	—	(2)	8.0	2.8	(0)	—	—

^a Harvest Season extends from July 1 to June 30.

influence harvest rates. The statewide declining harvest trend was marginally significant using a resampling, two sample test ($P = 0.06$) and was significant when a t-test was used ($P = 0.033$). A declining trend in the Beaufort Sea was not detected. The decline in annual harvest in the Chukchi/Bering seas area mimicked the statewide decline and was marginally significant using a resampling, two sample test ($P = 0.06$) and was significant when a t-test was used ($P = 0.036$).

Hunters from villages harvesting Beaufort Sea stock (Northern Area) polar bears accounted for 40.1% of the total state-wide kill, and hunters from villages harvesting from the Chukchi/Bering seas stock (Western Area) accounted for the remaining 59.9% of the kill. The sex ratio of the harvest from 1992–96 was 68:32, males to females. The sex ratio for the Chukchi Sea region approximated the long term 2:1, male:female, ratio;

while the Beaufort Sea region more closely approximated a 3:1, male to female (Table 3). Complete information on the age and sex of harvested bears was available for 66% of the kill.

Average age classes of harvested polar bears are presented in Table 4. The harvest age class composition during 1990 to 1995 was 12.8% cubs, 31.5% sub-adults, and 55.7% adults (Table 4). Long term differences in the sex ratio were not detected for either the northern or western areas, although annual variation by region were evident. Mean age of harvested polar bears is presented in Table 5.

Statewide, harvests occurred in all months. The greatest monthly harvest for the period occurred during December (16.0%). The combined months of November to May, when the pack ice is in proximity to shore,

Table 6. Monthly harvest of polar bears in the Beaufort, Chukchi and Bering Seas (1990–1996).

	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
Beaufort Stock*	1 (2.8)**	9 (4.3)	15 (7.1)	34 (16.0)	42 (19.8)	35 (16.5)	13 (6.1)	4 (1.9)	7 (3.3)	21 (9.9)	25 (11.8)	6 (2.8)	212 (100)
Chukchi/ Bering Sea	2 (0.7)	0 (—)	0 (—)	2 (0.7)	5 (1.7)	46 (15.6)	66 (22.5)	34 (11.6)	46 (15.7)	43 (14.6)	39 (13.3)	11 (3.7)	294 (100)
Total	3 (0.6)	9 (1.8)	15 (3.0)	36 (7.1)	47 (9.3)	81 (16.0)	79 (15.6)	38 (7.5)	53 (10.5)	64 (12.6)	64 (12.7)	17 (3.4)	506 (100)

* Beaufort Sea Stock harvest communities include Kaktovik, Nuiqsut, Barrow, Wainwright and Atkasuk.

** Percentage of annual harvest in parentheses.

accounted for 84.2% of the harvest. The months of June to September, when the pack ice is retreating to its minimum, accounted for only 8.8% of the harvest. Differences in the chronology of the harvest were evident between the Beaufort Sea region and the Chukchi and Bering seas region. The harvest in the northern area was bimodal and favored the October to December (52.3%) and April to May (21.7%) periods. In the western area the harvest was more evenly distributed through the mid-winter and spring months of December to April (93.3%) (Table 6). The pack ice is generally absent from this area during July to October resulting in low harvests (1.4%) during this period.

Genetic verification of Alaska hunter killed polar bears

To verify the sex of harvested bears, 177 muscle and tissue samples were analyzed using genetic techniques by LGL Research Associates Inc. The samples were analyzed according to techniques described by Amstrup *et al.* 1993, “Sex identification of polar bears from blood and tissue samples.” Sex could not be determined for 30 samples due to tissue degradation and subsequent desiccation which prevented DNA amplification. Of the remaining 147 samples analyzed 87 (59%) were male and 60 (41%) were female. This sample included 139 bears which were field-sexed and 8 bears for which the sex was recorded as unknown. The sex was correctly identified for approximately 86% ($n = 139$) of the harvest. The sex was reversed for 19 bears.

A number of factors appear to contribute to incorrect sex identity of harvested polar bears. Incorrect sex is reported by both the hunters and the taggers. Many of the misidentifications occurred when multiple bears

were harvested and the sex associated with a hide or skull was not properly remembered or reported. In other cases, sexual characteristics on the hides were incorrectly identified. Thirteen of the 19 bears that were incorrectly sexed were subadults or cubs. The gross error rate of 13.6% (19/130) is cause for concern over the accuracy of the sex identity of harvested polar bears. However, when the sex of litter mates, or same-age adults from multiple harvests, are transposed, the number of males and females harvested remains accurate, and there is a less serious effect on the accuracy of the harvest data. When errors in sex identification result in a net overestimate or underestimate of harvest of either sex the problem becomes more serious. In this study with 19 incorrectly sexed bears, 12 were reported as males when they were females and seven were reported as females when they were males. Thus seven of each sex “cancel” each other in terms of the overall sex composition of the harvest. Thus five more females were killed than were reported.

Of the total 114 bears which were aged (including the 16 incorrectly sexed bears), there were 12 male cubs, 5 female cubs, 17 female sub-adults, 22 male sub-adults, 31 female adults, and 27 male adults. A bootstrap analysis provided a 95% confidence intervals for each sex/age class. A significant bias (i.e., the 95% CI does not include zero) was observed for female sub-adults and all males and all females. This result is consistent with our raw numbers showing 12 females and 7 males were mis-identified. The proportion of mis-sexed bears varies with age-class and sex. However, there appears to be a bias to report sub-adults and dependent animals as males. Adult female bears appear to suffer a significantly lower rates of mis-sexing than sub-adult females and than females over all age-classes.

Analysis of factors affecting the composition of the Alaskan polar bear harvest: evaluation of the effectiveness of the North Slope Borough/Inuvialuit Game Council Agreement re: take of females and dependent polar bears

The factors affecting the sex and age composition of the polar bear harvest in Alaska were assessed with log-linear analysis. A manuscript on the results is in preparation. Polar bears harvested between 1 July 1980 and June 30, 1995 that had been sexed and had been aged by counting cementum annuli in teeth were selected for analysis. Each bear was assigned an age class: Adults (animals older than 5 years), sub-adults (animals older than April 30 of their 3rd year and younger than five years), C2 cubs (cubs younger than May 1 of their third year and older than 1 year), C1 cubs (cubs younger than 1 year). Polar bears harvested in the southern Beaufort Sea and Chukchi Sea stocks were analyzed separately.

The following factors affecting the sex and age composition of the harvest were considered: mode of transportation, the season of the harvest; and, in the southern Beaufort Sea region, provisions of the agreement between the NSB/IGC Agreement. We evaluated whether the sex or age of bears harvested from boats was different from those harvested from ice or land. Seasons were assigned to reflect the availability of polar bears for harvest based on distinct lulls that occur in hunting: spring (Jan 1 through June 30) or fall (July 1 through December 31). The NSB/IGC Agreement was investigated to determine its effect on the adult sex ratio and on the cub composition of the harvest using separate log-linear analyses. Because the NSB/IGC Agreement restricts the harvest of adult female bears only, its affect on the sex ratio of harvested polar bears was examined with a reduced model that included only the adults. To determine the effect of the NSB/IGC Agreement on the take of cubs a reduced model that disregarded sex was used because the NSB/IGC Agreement restricted the take of cubs without regard to sex. A power analysis of log-linear modeling was used to determine the strength of the analysis concerning the effect of the provisions of the NBS/IGC on the take of cubs.

Harvest season affected the age-class and the sex-class structure of the harvest. In the fall harvest season, sub-adults and C2 cubs constituted a significantly greater share of the harvest than in the spring harvest season. Females constituted a significantly greater share of the harvest in the fall than in the spring.

Although the overall sex ratio was not significantly different pre and post passage of the NSB/IGC Agreement, an analysis of the adults alone found that the ratio of adult females to adult males dropped significantly

following implementation of the NSB/IGC Agreement. Although the harvest of dependent animals declined following passage of the NSB/IGC Agreement, a power analysis determined that the effect of the NSB/IGC Agreement on the harvest of cubs was not great enough to be detected with the available data.

For the Chukchi/Bering seas population the mode of transportation was found to affect the overall sex ratio of the harvest. Harvests occurring from boats had a significantly greater chance of taking females than did harvests from land-based modes of transport. There were significantly more bears harvested from boats in the spring than in the fall which reflects the increase in the use of boats for hunting in the spring. The effect of mode of transportation on the Beaufort Sea population has not been evaluated.

Comparisons of the sex-age composition of harvest and population: Alaska Beaufort Sea population

In collaboration with Steve Amstrup we compared the sex/age composition of polar bears harvested from Alaskan Beaufort Sea villages with the sex/age composition of the polar bear population of the southern Beaufort Sea. The sex and age composition of the harvest was based on bears for which the sex and age was available in the harvest database ($n = 1089$) from 1980 to 1994. The sex/age composition of the population was estimated from the research database, determined through a long term mark/recapture study ($n = 3,243$ captures/recaptures) from 1981–1992. Four age-classes were assigned to polar bears based on criteria described previously. The overall proportions of bears in each sex/age class in the harvest database was compared to the population capture database. Data from each harvest year (defined as July 1 through June 30 of the following year) for both the harvest and population databases were treated as independent samples in a bootstrapping routine to provide an estimate of the confidence limits around the estimated proportions of bears in each sex/age class.

The preliminary analysis indicates that sub-adult males were significantly over represented, while cubs of the year were significantly under represented in the harvest (Table 7).

Contaminants in Alaska polar bears

A biological sampling program began in fall/winter 1996 to coincide with the polar bear harvest period. The objectives of the program are to determine heavy metal concentrations in the muscle, liver, and kidneys, levels of methyl mercury in muscle tissue, and

Table 7. Sex/age composition of the southern Beaufort Sea polar bear harvest and the southern Beaufort Sea polar bear population. Values are percentages based on the polar bear harvest database and on the research population database. Lower confidence limits (LCL) and upper confidence limits (UCL) are based on the 95 percentile tails of bootstrap distributions. A star (*) indicates an age/sex class that was significantly over or under represented in the harvest.

		Male			Female		
		LCL	%	UCL	LCL	%	UCL
Adults	Harvest	18.40	27.90	37.60	13.30	20.40	27.50
	Population	6.52	15.40	24.40	21.80	31.80	41.60
Sub-Adults	Harvest	17.60	26.50*	35.80	6.91	11.10	16.40
	Population	3.62	7.76	14.20	4.84	8.09	12.00
C2 Cubs	Harvest	4.22	8.41	13.50	0.85	2.66	5.02
	Population	4.32	7.85	12.20	5.67	9.08	13.20
C1 Cubs	Harvest	0.00	1.77*	4.33	0.00	1.33*	2.51
	Population	6.11	9.41	14.20	6.99	10.70	14.70

organochlorine concentrations in fat tissue of adult male polar bears. Adult males were selected to reduce variation in contaminant levels due to sex and age and parsing the final data set and to not encourage hunting of adult females.

Incidental take

Polar bear/human interactions

Under provisions of the MMPA, final regulations to authorize the incidental, non-lethal take of small numbers of polar bears during oil and gas activities in the Beaufort Sea region (excluding Arctic National Wildlife Refuge) were published November 16, 1993 and became effective December 16, 1993. Under the incidental take regulations industry may request From the FWS a Letter of Authorization (LOA) for the incidental, non-lethal take of polar bears while conducting operations polar bear habitat. Issuance of a LOA is contingent upon the submission and approval of an operator polar bear awareness and interaction plan, a plan to monitor the effects on polar bear during authorized activities, and a plan of cooperation with Natives to minimize adverse effects on the availability of marine mammals for subsistence uses. Annual reports are required prior to issuance of subsequent LOAs. Twelve LOAs were issued to oil and gas industries for exploration (seismic and drilling), development, and production activities in the Beaufort Sea region in 1994, five were issued in 1995, and nine were issued in 1996.

During the fall and early winter aggregation of polar bears, numbering up to 40 animals, have gathered near

some coastal villages. People living in remote coastal villages within the range of polar bears have expressed concerned personal safety. In some North Slope villages local polar bear monitors have been hired by the North Slope Borough to patrol when bears are present. Continued efforts by the North Slope Borough's Department of Wildlife Management in monitoring problem situations and for hazing bears from villages has been responsible for conservation of bears in this area and for compliance with harvest guidelines contained in the agreement with the Inuvialuit Game Council, Canada.

Habitat conservation strategy for polar bears in Alaska

The *Habitat Conservation Strategy for Polar Bears in Alaska* (Strategy) was completed in August 1995. The primary sources of information for the Strategy included published and unpublished scientific studies and the traditional knowledge of polar bear habitat use from Inupiat and Yupik Natives. The Strategy identifies measures to conserve and protect important denning and feeding habitats and seasonal use areas.

Twelve villages in northern and northwestern coastal Alaska were canvassed to gather information about polar bear habitat use from native hunters and experts. Information gained from traditional knowledge, which is often passed down orally and based upon years of observation, was obtained through interviews. The product of these interviews were a series of maps which depict traditional knowledge of seasonal polar bear habitat use, such as denning and feeding areas, observed within the area used by the residents for hunting or

traveling. A technical report summarizing the survey protocols and results of the Native knowledge survey of polar bear habitat use is in the final preparation.

The Strategy proposed measures to further the goals of the 1973 Agreement, which include the development of a Village Communication Plan, development of a

Polar Bear Advisory Council, through continued recognition of the importance of the status of the Arctic National Wildlife Refuge for maternity denning, and through further cooperation and coordination in international conservation initiatives. Lastly, the Strategy identifies a number of important research needs regarding polar bear and habitat relationships including the role and effect of contaminants in the environment.

Polar Bear Research in Western Alaska, Eastern and Western Russia 1993–1996

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Joint U.S./Russian project

The U.S./Russia cooperative research project on polar bears (*Ursus maritimus*) that seasonally occur in waters of western Alaska began in 1990. In addition to the 130 female polar bears captured and fitted with satellite collars between 1986 and 1992, another 32 females were collared between 1993 and 1995 in this population. Capture activities were extended west into the East Siberian Sea during spring 1993 and 1994. Capture activities ended in Russian portions of the Chukchi Sea and the East Siberian Sea in 1994. Data analyses are on-going and manuscripts are being prepared for publication.

A joint research project between Russian, Norwegian, and American scientists on polar bear ecology in the Severnaya Zemlya Islands of the east-central Russian arctic that was initiated during 1991, was expanded in 1994 to include larger areas of the Laptev and Kara seas when 8 additional satellite collars were deployed on adult females. In spring 1995, the study area was expanded into the Novaya Zemlya and Franz Josef archipelagos of the Kara and Barents seas when 20 satellite collars were deployed on females with cubs of the year. Collars were designed to function for 2 years, and 12 to 14 collars are still transmitting.

Research in both areas have focused on examining the interrelationships between polar bears and their sea

ice habitats. In the Chukchi Sea, remotely-sensed multi-spectral satellite sea ice data were combined with satellite locational data from female polar bears to develop a methodology to examine habitat use (Arthur *et al.* 1996). This methodology is being applied to the entire locational data set for the Chukchi Sea between 1986 and 1992 to assess habitat use patterns. Unfortunately, the remotely-sensed sea ice data have a coarse resolution (pixel size is a 25 km square), and available sensors can only distinguish open water from sea ice. This analyses is necessarily limited to the ice cover and ice edge variables. Another limitation is that the multi-spectral sensors are limited to visible bands, therefore, data are only available for days when cloud cover is limited.

In western Russia, a cooperative effort between the Russian Academy of Sciences and the Alaska Science Center has been using simultaneously-collected passive microwave and active real-aperture radar data from Russian satellite-series OKEAN to map ice cover and types in the Barents, Kara, and Laptev seas. The satellite sensors are not hampered by cloud cover or darkness. Spatial resolution is approximately 15 km and 1.2 km for the microwave and radar sensors, respectively, although effective pixel size has been averaged to 3 km square for analyses. Within each pixel, the concentrations (percent cover) of four habitat types are estimated: multi-year ice, annual ice, open water, and heavily deformed areas within annual ice. Data processing is

underway, and analysis of sea ice habitat use will occur within the next year. Manuscripts are being prepared on the methodologies used to process and interpret the remotely-sensed sea ice data.

Population estimation project

A major goal of the research in western Alaska and eastern Russia was to determine population size and status of polar bears that occur in the Bering and Chukchi seas. As part of that effort, several census methodologies were tested in the Beaufort Sea during spring 1994. The test was intended to simulate a ship-based survey along the ice edge in the Chukchi Sea, and was first attempted during September 1993. The ice edge was 120 to 190 nm offshore, and survey design could not be accomplished as the ice was out of range of the helicopter. The effort was repeated during June 1994, but no effective ice edge existed to concentrate bears. A 100×60 nm survey block was identified offshore from Prudhoe Bay and a larger 200×100 nm block was overlaid centered on the initial survey block. A detailed report on the results of the test is being completed and a the double observer design was described in Manly *et al.* (1996). The following materials are highlights from the final report.

Mean density per km^2 of polar bear groups and individuals are estimated during the survey period and within the 100 nm by 60 nm study region. Emigration and immigration may both have occurred during the survey. Total population size estimates are based on the concept of estimated “mean density” during the survey period as if “instantaneous” counts of abundance could have been made each survey day and averaged.

Fifteen polar bear groups were sighted from the Bell 212 platform, while the survey crew was following the standard protocol. Small data sets are subject to relatively high variation. A data set with four to five times this number of detections would be required to achieve an estimate of mean group density with a coefficient of variation of approximately 12.5%. The coefficients of variation for the current estimates range from about 33% to 100% depending on whether the logistic model is used to estimate the proportion of groups missed on the inside edge of the survey strip.

The minimum point estimate for “mean” polar bear density in the study area for the period of concern was: $(0.0028 \text{ groups}/\text{km}^2) (1.1428 \text{ bears}/\text{group}) = 0.0032 \text{ bears}/\text{km}^2$.

This estimate is based on the observed density of groups within 1000 m of the inside edge of the survey strip and mean size of groups within 200 m of the inside

edge of the survey strip. Using this minimum estimate of average density during the survey, the estimated “mean” population size in the 100nm by 60nm study area is 66 polar bears. The standard error for this minimum estimate is about 22 bears based on an approximate coefficient of variation of 33%.

The best fitting model for the observed perpendicular distances to polar bear groups was judged to be the negative exponential with 1 cosine adjustment term. This model has the minimum Chi-square goodness-of-fit statistic and nearly the minimum value of the Akaike Information value. The best estimate of the mean group size is judged to be 1.2318 bears/group based on the Drummer’s negative exponential model for size-biased line transect sampling. With no projected increase in the estimate for the proportion of groups missed on the inside edge of the survey strip this estimate for mean polar bear density is: $(0.003625 \text{ groups}/\text{km}^2)(1.2318 \text{ bears}/\text{group}) = 0.004465 \text{ bears}/\text{km}^2$, or a mean population size of 92 polar bears in the study area. Again the coefficient of variation for this estimate is about 33%.

The best estimate of the proportion of groups missed on the inside edge of the survey strip is 0.1218, or about 12%. If the above estimate is adjusted for this potential bias, the estimated mean polar bear density is: $(0.004465 \text{ bears}/\text{km}^2)/(0.8782) = 0.005295 \text{ bears}/\text{km}^2$, or a mean population size of 109 polar bears in the study area. This estimate (0.005295 bears/ km^2 , or 109 polar bears) is judged to be the best point estimate of the mean density and mean population size. Unfortunately, the coefficient of variation for this estimate is about 100%. The coefficient increases dramatically due to poor precision in estimation of the proportion of groups missed on the inside edge of the survey strip, because of the small number of groups detected in the double sampling part of the survey protocol.

The maximum point estimate for mean polar bear density during the survey period is based on the negative exponential model, no reduction in observed mean group size, and with adjustment for the proportion on groups missed on the inside edge of the survey strip: $(0.004169 \text{ groups}/\text{km}^2) (1.4166 \text{ bears}/\text{group}) / (0.8778) = 0.006728 \text{ bears}/\text{km}^2$, or a mean population size of 138 polar bears in the study area. Again, the coefficient of variation for this point estimate is quite large based on the small sample sizes.

Recommendations concerning study design and statistical analysis of large scale polar bear surveys:

- Maintain double sampling with independent observers.

- Record distance to observed groups of bears, group size, activity, observer, and other variables which potentially affect probability of detection of groups.
- Maintain a consistent protocol with trained observers and pool observations across survey units to fit logistic regression functions (or line transect models for probability of detection) and estimate probability of detection given the observed values of predictor variables.
- Correct observed density in individual survey units for visibility bias using detection functions computed from pooled data.
- Based on computer simulations exercises with the 1994 data set, 60 to 70 detections of polar bear groups using the double sampling protocol should yield a total abundance estimate with about 12.5% coefficient of variation.

Other points:

1. (Spring 1994) (a) multi-year mark/recapture-tetracycline marking not practical due to extreme high levels of harassment for minimum benefit; (b) adaptive sampling (twin otter) impractical as implemented, distance between adaptive lines was 5 nm and was probably too far to detect nearby bears, no additional bears sighted on 11 additional lines (220 nm), maybe 1 nm separation between successive adaptive lines would be more effective
2. Twin Otter does not appear to be a suitable aerial survey platform for polar bears — effective transect width is reduced by 1/3 as compared to helicopter, differential sight picture (down angles and limited field of view) between front and rear observers, non-visible portion of transect below plane larger than helicopter
3. Helicopter marking was originally designed to consist of 3 days of marking followed by 3 days of surveying-altered after stopped tetracycline marking (see above), then continued marking throughout surveys except the final day

Adult male telemetry project

A pilot study of implanted satellite telemetry on adult males was initiated during spring 1996 in the Chukchi Sea near Wainwright, Alaska. The objective was to determine the feasibility of using subcutaneous implants of satellite transmitters with a percutaneous antenna to monitor movement patterns of adult males. Four adult males were captured during early April and implanted with the satellite unit. The implant unit was placed at the base of the neck, on the dorsal surface immediately anterior to the shoulder hump between the

two shoulder blades. A VHF ear-tag transmitter was also attached to relocate the animals repeatedly for a one month period following implant surgery. Three of the animals were recaptured after one month to examine the implant and determine the status of healing at the surgery site. The fourth bear was not recaptured because inclement weather prevented locating the animal before he moved 200 nm offshore, out of effective capture range. Surgery sites were healing as expected at recapture, without any signs of attempts by the bears to dislodge the implants or the VHF ear-tag transmitters.

Three implanted satellite transmitters functioned well for the initial 3 months after deployment and provided a large number of high quality location fixes. However, one transmitter failed after 30 days, all units had failed after 4 months (30 days, 87 days, 93 days, and 129 days). A second recapture effort was scheduled for November 1996, but inclement weather prevented this effort. The second recapture has been rescheduled for March 1997. Cause of premature failure of the implanted transmitters can not be determined without recapturing the individuals. Speculation is that broken percutaneous antennas are the problem.

Polar bear den survey workshop

A workshop on polar bear den survey methods was co-sponsored by the Alaska Science Center (USGS-BRD) and Marine Mammals Management (USFWS). The meeting was held in Anchorage in early December 1996, with the following participants: Stanislav E. Belikov, Andrei N. Boltunov, and Nikita G. Chelentsev, All-Russia Research Institute for Nature Conservation, Moscow, Russia; Nikita Ovsvyanikov, Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow, Russia; Mikhail S. Stishov, Wrangel Island State Nature Reserve, Moscow, Russia; Tom Evans, Susi Kalxdorff, and Scott Schliebe, USFWS, Marine Mammals Management, Anchorage, Alaska; Lyman L. McDonald, WEST Inc., Cheyenne, Wyoming; and Gerald W. Garner, USGS-BRD, Alaska Science Center, Anchorage, Alaska.

The workshop reviewed existing den survey methods used by Russian biologist on Wrangel and Herald islands and discussed various options to improve the precision of the estimates of the numbers of maternity dens. A detailed report on the workshop proceedings and a proposal for a one season intensive study to test new methods is being prepared. The proposed test would be jointly sponsored by the Alaska Science Center, Marine Mammals Management, Wrangel Island State Nature Reserve, and the All-Russia Institute for Nature Protection.

Other research projects

The studies of polar bear genetics to determine the degree of separation between polar bear stocks in the Chukchi and Beaufort seas continues, and data analyses are on-going. A manuscript on the results of this work is anticipated this summer. The western Alaska is also participating in the international project, which is reported elsewhere in this volume and will not be repeated here.

Sera from blood samples from an additional 700 polar bears captured in western Alaska, eastern and western Russia, and the Canadian arctic have been screened using a neutralization test for antibodies of canine distemper virus (CDV) to determine the potential for incidence of phocine distemper virus (PDV) in polar bears (Follmann *et al.* 1996). The second phase of this research to determine if the positive antibody titer to CDV is actually PDV is on-going with cooperators from the University of Alaska-Fairbanks, the Washington Animal Disease Diagnostic Laboratory, and the USDA Plum Island facility. These samples were also screened for infectious canine hepatitis. Data analyses is on-going.

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Polar Bear Research in the Beaufort Sea

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Introduction

Research activities in the Beaufort Sea during the 1980s and early 1990s dealt primarily with: describing movement patterns of polar bears in the Beaufort Sea region and defining bounds on the population; attempting to assess the size and status of the population; and determining the distribution timing and importance of polar bear maternal denning efforts in the Beaufort Sea. This report summarizes work completed after the last meeting of the Polar Bear Specialists Group in 1993 (a list of the resulting publications is in the appendix).

Movements and activities of polar bears

We were able to confirm great mobility of polar bears – some bears made linear movements of over 5,000 km annually. Polar bears were not nomads, however, as most were seasonally faithful to geographic regions and occupied definable activity areas (Figure 1, Table 1).

Polar bears captured along the Beaufort Sea mainland limited their movements largely to the southern Beaufort Sea and northeastern Chukchi Sea (Figure 2). Bears captured in the Chukchi Sea were relocated in the Beaufort Sea far less often than they were relocated in the

Chukchi (Figure 3). Although they show general fidelity, particularly at certain seasons (Figure 4) Beaufort Sea polar bears probably are not genetically isolated from members of other polar bear populations (Cronin *et al.* 1991, Durner and Amstrup 1995).

Movement patterns and activities of female polar bears (Table 2, 3) varied according to the time of the year and reproductive status. Females with cubs travelled at slower rates, but were more active, than those with older young or those not encumbered by young. The lowest movement rates generally occurred in late winter when suitable foraging habitats are fewest and when bears may restrict movements to conserve energy (Messier *et al.* 1992, 1994). High movement rates in early winter may reflect the increase of favored foraging locations resulting from the expansion of autumn sea ice. Movements from the central Beaufort Sea toward the east and west in winter, may be related to the persistent leads that develop there, and movements to the north in summer and back to the south in autumn, probably correspond to ice ablation and formation in coastal waters. Movements and activities of polar bears were not always concordant (Figure 5) however.

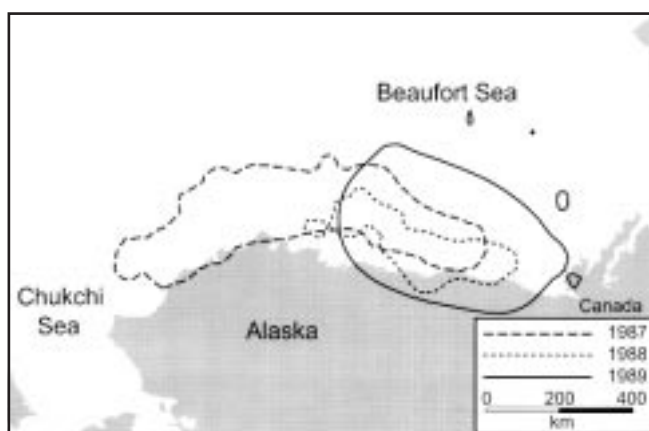


FIG. 1. Activity area boundaries calculated with the harmonic mean method for satellite radio-collared polar bear #6201. Boundaries shown enclose 95% of the locations recorded each year. Note variation in geographic areas occupied among years.

Table 1. Sizes (km²) of annual activity areas for 96 satellite radio-collared female polar bears in the Beaufort Sea, 1985–93. Contours surrounding 95% and 50% of observed points are shown for both the adaptive kernel (Worton 1989) and harmonic mean methods (Dixon and Chapman 1980). Convex polygon areas are shown for comparisons to other studies.

Method	\bar{x}	Minimum	Maximum	S.E.
Adaptive kernel				
95% contour	197,130	25,580	644,800	13,874
50% contour	34,851	2,979	112,700	2,619
Harmonic mean				
95% contour	162,124	12,730	596,800	13,194
50% contour	20,238	1,553	61,760	1,456
Convex polygon	178,033	14,440	616,800	13,762

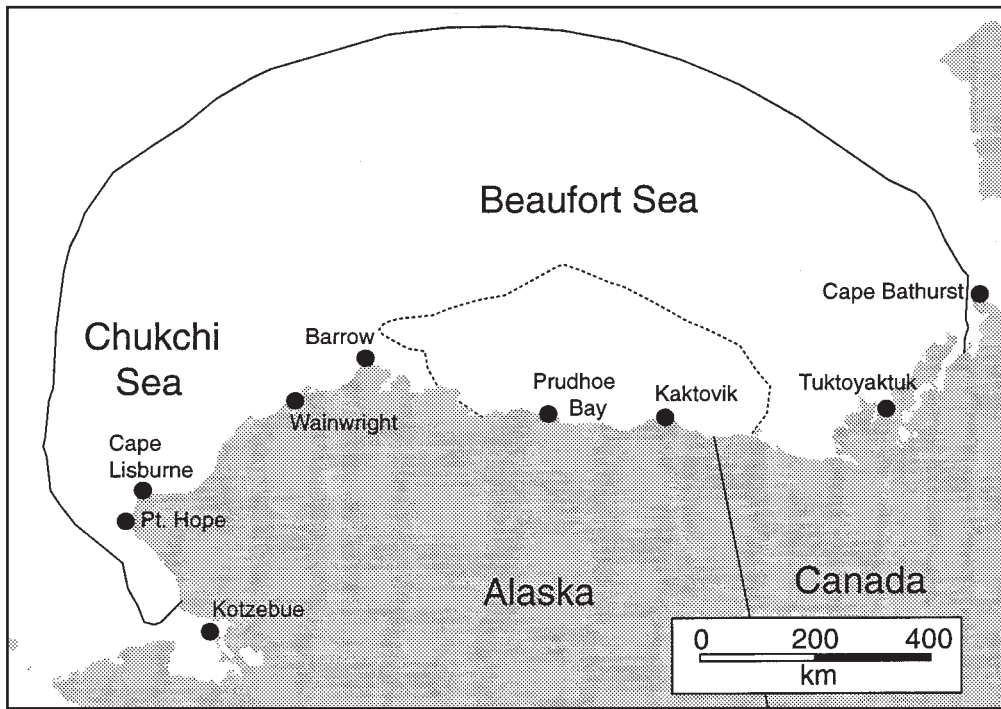


FIG. 2. Approximate bounds (95% contour) of the Beaufort Sea polar bear population (solid), and core (50% contour) activity area (dashed) determined by harmonic mean analysis of satellite radio-telemetry data collected 1985–1993. Not including land areas, the population boundary enclosed 939,153 km² and the core area enclosed 122,089 km². Also shown are place names used in the text.

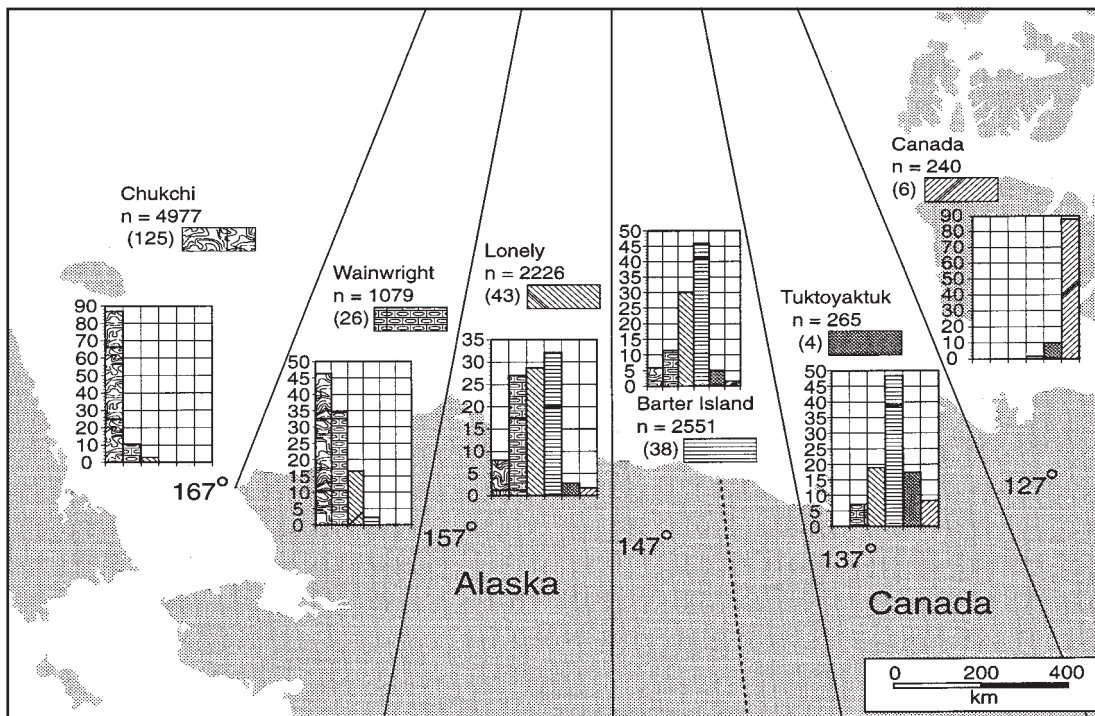


FIG. 3. Numbers and positions of relocations (bears) of satellite radio-collared polar bears captured in each of 6 longitudinal zones within the Beaufort Sea. Histograms illustrate proportions of those relocations made in each zone (e.g., 32% of the 2226 relocations of bears originally captured in the Lonely zone were recorded in the Barter Island zone; 47% of the 1079 relocations of bears captured in the Wainwright zone were recorded in the Chukchi zone).

The distribution of polar bears is thought to be closely related to the distribution of ringed seals (*Phoca hispida*) and bearded seals (*Erignathus barbatus*) (DeMaster and Stirling 1981), their primary prey. Predation by polar bears can have a significant impact on ringed seal populations (Hammill and Smith 1991), by modifying seal behavior (Stirling 1977) and distribution. Daily activity cycles of bears (Fig. 6) probably correspond with vulnerabilities in seal activity patterns (Kelly and Quakenbush 1990). To little is known, however, about the interactions between bears and seals. Logistical obstacles make understanding seals, sea ice, and the movements of polar bears a formidable task. Because polar bears may be important indicators of the welfare of the Arctic and the world (Stirling and Derocher 1993), overcoming the obstacles is necessary.

Population dynamics of polar bears

Major changes in population size often provide important opportunities to understand population dynamics (McCullough 1979). Amstrup *et al.* (1986) presented evidence that the population in the early 1980s was

approximately the same size as it had been in the late 1950s — the early years of aerial hunting — and that the population had been much lower during the intervening period as a result of that aerial hunting. This study corroborated that pattern and suggested the population of the Beaufort Sea region may have been growing at up to 2% per year since the early 1970s. That is near the maximum that could be expected given the population is being harvested (Taylor *et al.* 1987). Prior to aerial hunting, polar bears in Alaska were largely unperturbed, with a harvest limited to small numbers taken by subsistence hunters (Amstrup and DeMaster 1988). It is reasonable to conclude the population prior to aerial hunting was high, and probably near K, and that it is now nearly as large.

We estimated, with 95% confidence, that annual survival of adult female polar bears is between 0.95 and 0.98. This is higher than any previous estimate, and in line with what appears to be needed to sustain populations of large mammals (Eberhardt 1985). Estimates of survival of cubs (0.61–0.70) and yearlings (0.75–0.93) were lower than most previous estimates.

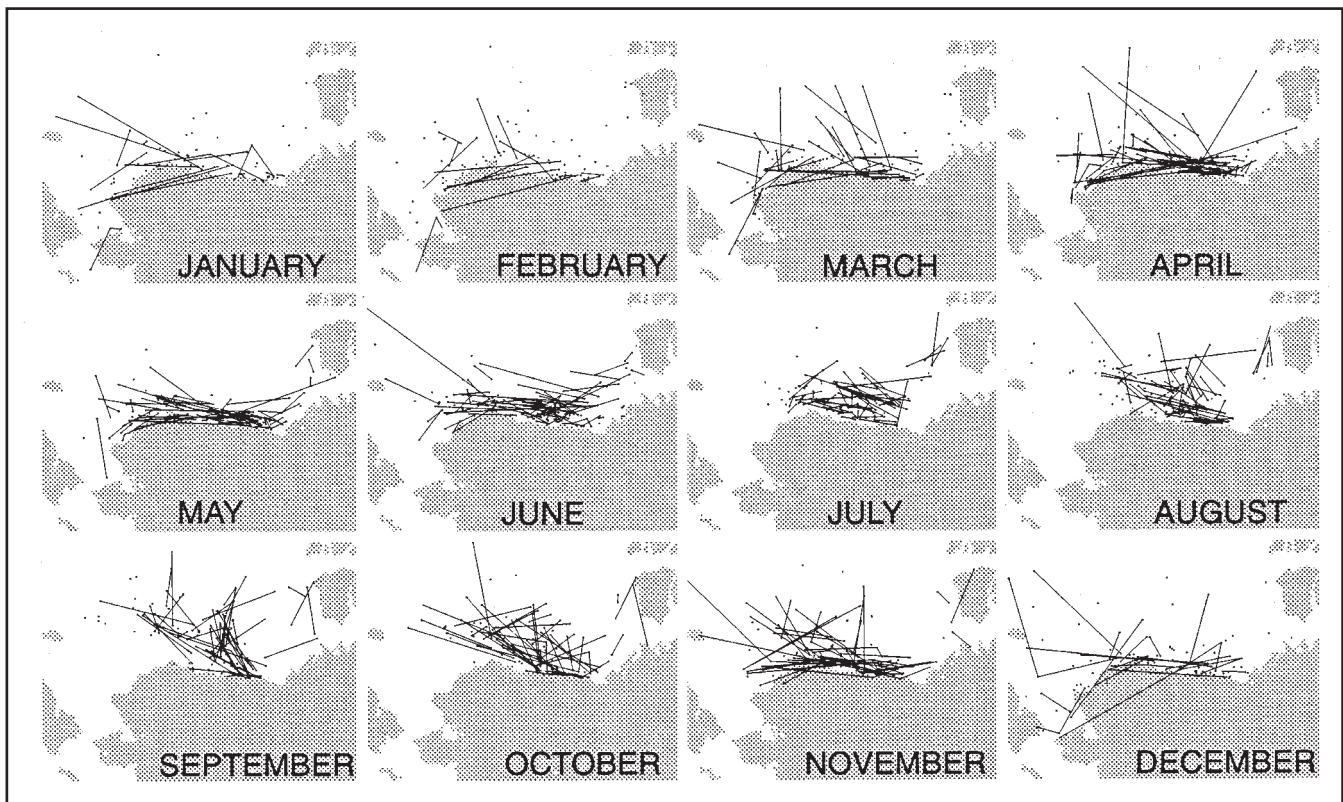


FIG. 4. Monthly harmonic mean centers of activity for satellite radio-collared female polar bears in the Beaufort Sea, 1985–1993. All bears and all years are grouped by month. Lines connect activity centers from one year to the next for the same individual bears. Note that bears were most likely to return to the vicinity of previous activities during the summer months.

Table 2. Movement rates of satellite radio-collared female polar bears in the Beaufort Sea, 1985–93, comparing known and suspected reproductive status. Reproductive status was confirmed if visual observations were obtained regularly enough to know that young survived through each stage of life.

<i>Reproductive Status</i>	<i>Movement Rate (km/h)</i>			<i>Wilcoxon Z</i>	<i>P^b</i>
	<i>n^a</i>	\bar{x}	<i>S.E.</i>		
Females With Cubs					
Confirmed	1012 (34)	0.51	0.016	4.39	0.0001
Suspected	776 (38)	0.59	0.020		
Females With Yearlings					
Confirmed	1100 (39)	0.55	0.020	2.74	0.0060
Suspected	1301 (39)	0.60	0.010		
Females With 2-year-olds					
Confirmed	184 (13)	0.44	0.030	1.07	0.2850
Suspected	499 (26)	0.49	0.020		

^a Numbers of satellite relocations (numbers of individual PTT-equipped polar bears).

^b Probability of difference this great between females of confirmed and suspected status occurring by chance.

Table 3. Estimates of annual activity areas for satellite radio-collared female polar bears in the Beaufort Sea, 1985–93. Estimates refer to (1) the total areas within contour lines generated by the harmonic mean method, that circumscribe 95% and 50% of relocations, (2) the total areas circumscribed by polygons defined by the convex polygon (CP) method. Reproductive status is recorded as the modal value for each year of monitoring.

<i>Status</i>	<i>Activity Area Size (km²)</i>			
		<i>95%</i>	<i>50%</i>	<i>CP</i>
Females with cubs	\bar{x}	100,812	13,837	105,932
	S.E.	31,420	2,778	33,723
	<i>n</i>	13	13	13
Females with yearlings	\bar{x}	148,572	15,796	161,593
	S.E.	36,497	3,249	48,308
	<i>n</i>	12	12	12
Single females*	\bar{x}	162,772	21,167	183,595
	S.E.	19,265	2,203	18,987
	<i>n</i>	37	37	37
Females that denned during monitoring period	\bar{x}	35,042	4,308	69,012
	S.E.	3,370	710	18,739
	<i>n</i>	5	5	5

* Core activity areas of single bears were larger than those of bears that entered dens during the period of monitoring ($F = 3.65$, $df = 3$, $P = 0.02$; HSD = 3.73, $df = 63$, $P = 0.05$). Other differences were not significant.

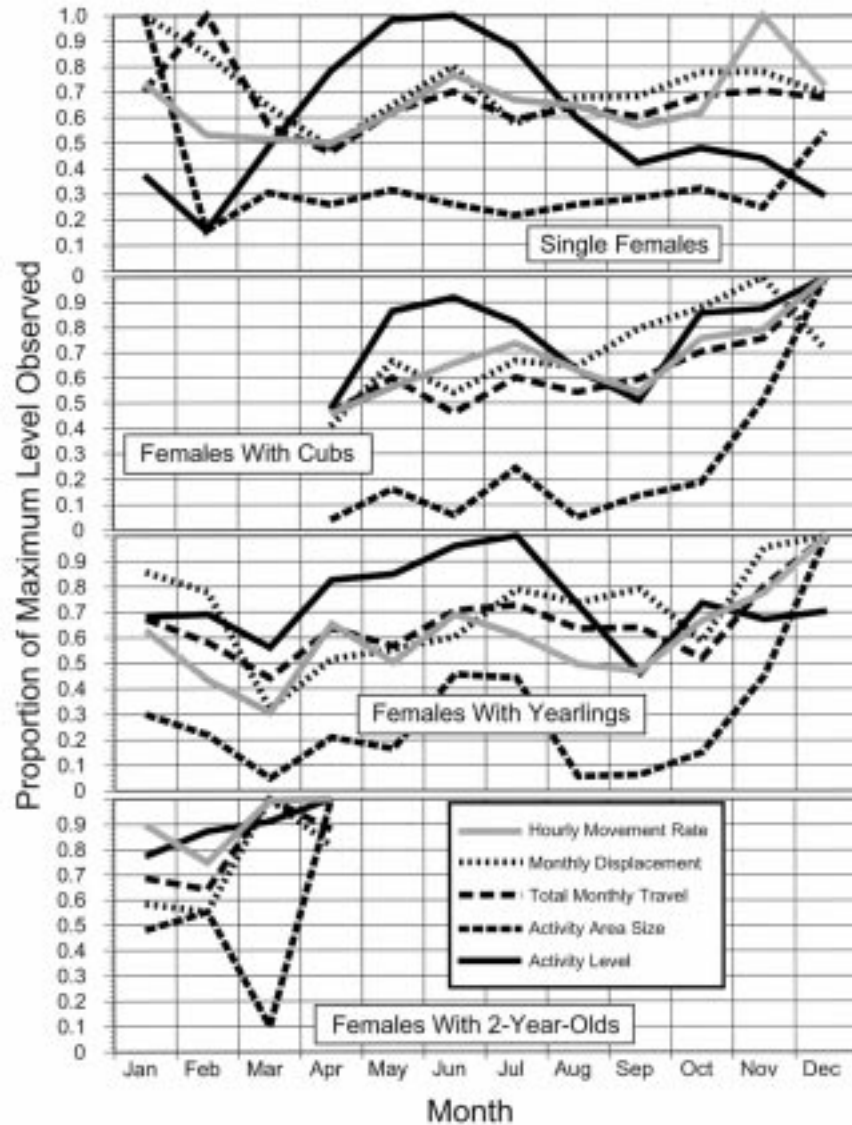


FIG. 5. Activity and mobility of satellite radio-collared female polar bears in the Beaufort Sea, 1985–1993. Note incomplete concordance of various measurements. Each value is expressed as a proportion of the maximum.

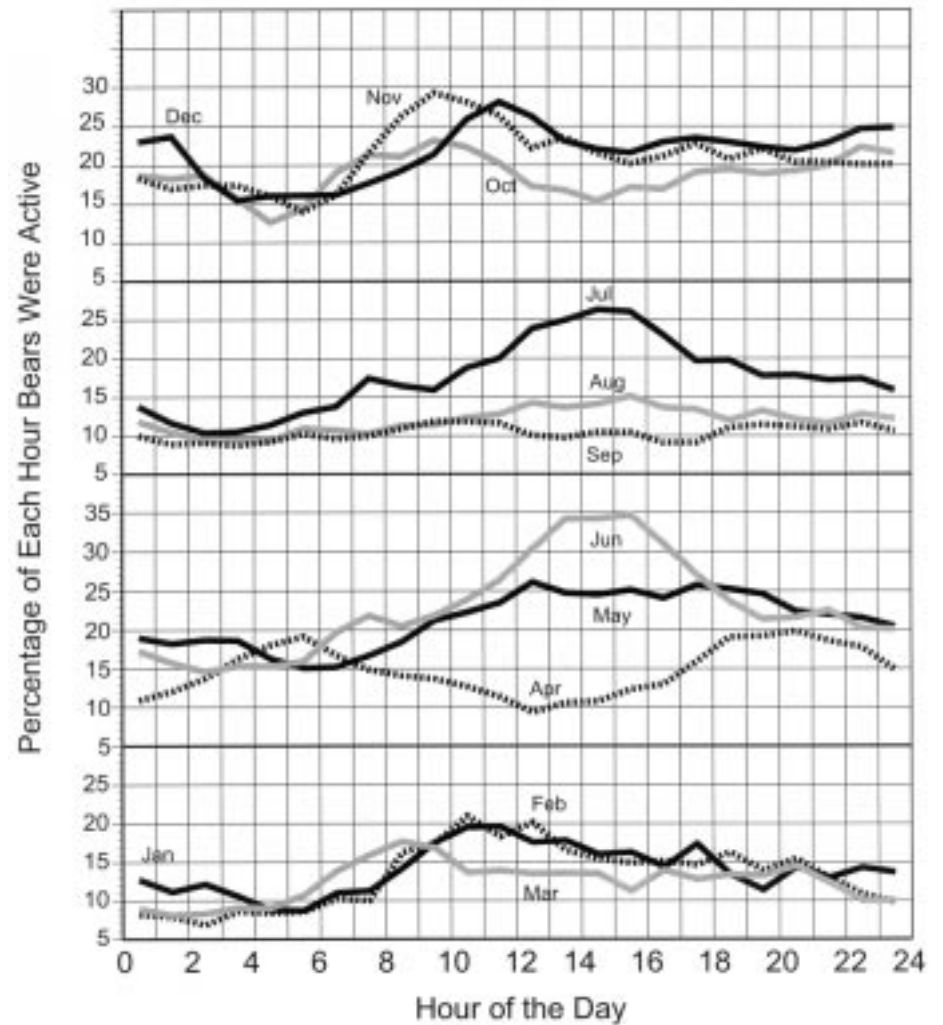


FIG. 6. Daily activity patterns (% hour active at each hour) of satellite radio-collared female polar bears in the Beaufort Sea, 1988–93. Bears of all reproductive status categories are pooled in this figure to illustrate overall activity patterns.

As a population increases toward K , the first negative effect of its own density is increased mortality of young (Eberhardt 1977, Derocher and Stirling 1992). At still-higher densities, age of maturity increases and then condition and productivity of mature animals declines (Fig. 7, 8). Finally, at the highest densities, survival of adults may decline (Eberhardt 1977, Fowler 1981). The changes in population composition, survival, and recruitment we observed, follow that pattern and appear to be typical signs of a population approaching K -carrying capacity (Eberhardt and Siniff 1977, McCullough 1979). Also, they are similar to atterns recently reported in Hudson Bay where the polar bear population also has grown (Derocher and Stirling 1992).

Although we observed what appeared to be density effects on the population, we were not able to learn how density influenced reproduction or survival. In terrestrial bears, harassment, or infanticide by large males may be a principal mechanism of density dependent population regulation (Young and Ruff 1982, McCullough 1981, Stringham 1983). Harassment of subadults by adult males at scavenging sites (Smith 1980) may be an important regulating factor among polar bears. In the autumn of 1996, we observed 28 polar bears scavenging the remains of a butchered bowhead whale (*Balaena mysticetus*). At first view, it appeared that the abundant food allowed the bears to coexist amicably. Two days later, however, upon revisiting the site, we observed that a yearling bear had been

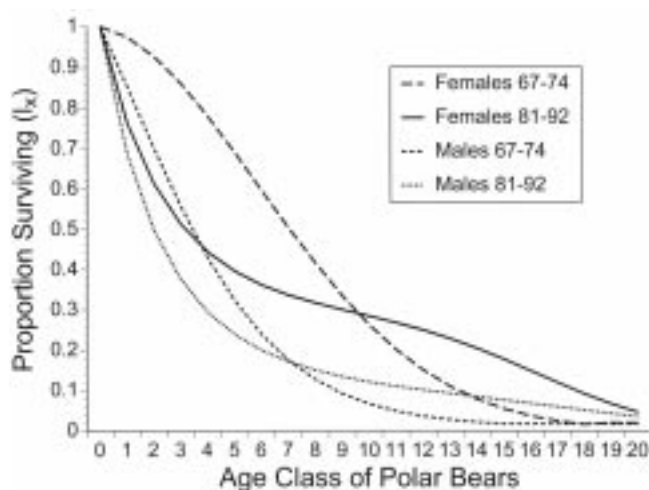


FIG. 7. Smoothed (Caughley 1977) I_x curves for polar bears in the Beaufort Sea during 1967–1974 and 1981–1992 study periods. Note that survival early in life was poorer and survival later in life greater during the 1981–1992 study period.

killed and several other bears were in the process of consuming it. Any effect male polar bears have on their population, however, is yet to be quantified.

Their life history features, and our observations, suggest that polar bears should be among the most K -selected of wild animals. They are not completely invulnerable to short-term perturbations of their environment, however. Survival and production of young in the Beaufort Sea population dropped in response to abnormally harsh winter conditions in 1974–75 (DeMaster *et al.* 1980). That response occurred in a density independent fashion and at a time when population size was low (Rogers 1987, DeMaster 1981). An understanding of predator/prey interactions and how those interactions are mediated by weather and sea-ice conditions is needed to understand the population dynamics of polar bears.

Polar bears in the Beaufort Sea now appear to be numerous, and appear to be showing some density-related effects in reproduction and survival. Hence, existing harvest apparently is within sustained yield. If an increased harvest, to a stable point (fixed removal yield; McCullough 1979) near MSY becomes the

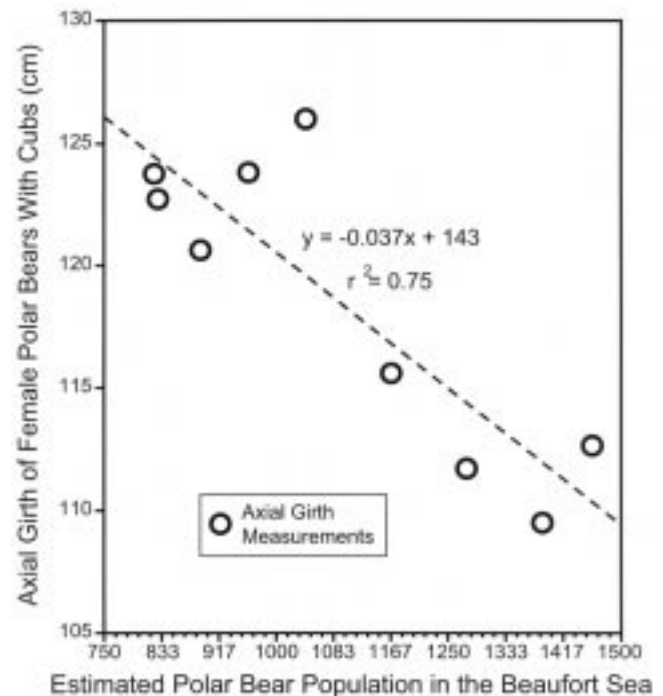


FIG. 8. Relationship between estimated size of the Beaufort Sea polar bear population and axial girth of female polar bears accompanied by cubs of the year in spring, 1967–1992. The fitted line was significantly different from “0” ($P = 0.002$). An r^2 of 0.75 means that 75% of the variation in axial girth was explained by population size alone.

management objective, much better and more timely estimates of population size and K will be needed.

Denning ecology of polar bears

In all recorded history before this project started, only 35 locations of polar bear maternity dens in Alaska were published (Lentfer and Hensel 1980). Many of those 35 were known only approximately, from reports of local residents and early explorers, and the degree of confirmation was highly variable. This dearth of records of dens led many to speculate that “Alaska’s” polar bears were really not “Alaska’s” but visitors from breeding areas in other countries. We found over 100 dens during this study, and verified that there are sufficient numbers of dens in the Beaufort Sea region of Alaska and Northwest Canada to account for the estimated population size here. Surprisingly, over ½ of the denning in this

region is on offshore sea ice, thus explaining the failure of earlier workers to find sufficient numbers of dens (Figure 9).

We discovered that polar bears, contrary to popular beliefs, did not den in the same place each time they were pregnant (Figure 10), but were faithful to the general geographic areas of previous dens. Polar bears also were largely faithful to the substrates of previous dens, either land or sea-ice. Most bears entered their dens in mid-November (Table 4).

We found more dens at sea than on land, but land denning along the Beaufort Sea coast appeared to be increasing through the duration of the study (Fig. 11). Because the sea ice is a less stable platform for denning than land, bears that denned at sea drifted up to nearly 1000 km during the winter. Hence, natural phenomena sometimes disrupted dens and the predictability of resources upon emergence of the female and her new cubs from their den was limited. The production of cubs from dens at sea, however, was not significantly different than that from dens on land.

Table 4. Chronology of polar bear maternal denning in the Beaufort Sea region of northern Alaska and northwestern Canada. Mean dates of entry and emergence and duration in dens are shown along with standard deviations of the estimates. Note that bears on the pack-ice occupied their dens for shorter periods than those on land.

<i>Substrate</i>	<i>Entry date</i>	<i>Exit date</i>	<i>Duration in den</i>
Land	11 November	5 April	147 days
	SD (22 days)	(9 days)	(22 days)
Pack ice	22 November	26 March	130 days
	SD (21 days)	(13 days)	(28 days)

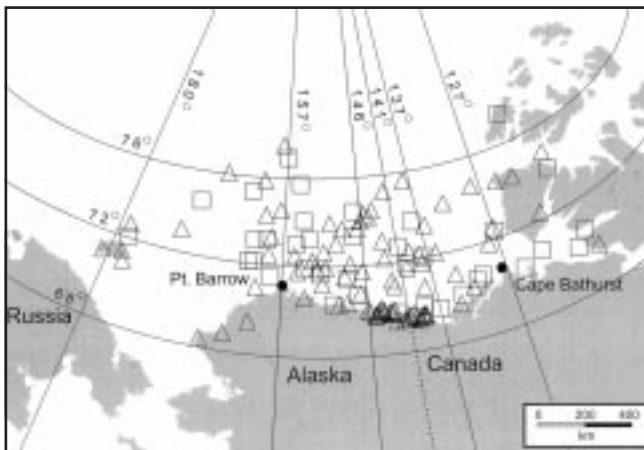


FIG. 9. Suspected (squares) and confirmed (triangles) polar bear maternity dens located by radiotelemetry between 1981 and 1992.

The preferred region for land denning was the northeast corner of Alaska and adjacent Canada. This region, which includes the “1002 area” of the Arctic National Wildlife Refuge, also holds the highest potential for discovery of commercial hydrocarbon deposits in the U.S. Clearly, there is the potential for many disruptions of dens in this region. Loss of a large portion of the productivity of the dens from this area could undermine recruitment of polar bears into the Beaufort Sea. Observations of polar bear dens that were exposed to varying levels of human disturbance, however, indicated that many denned bears that are exposed to human activities

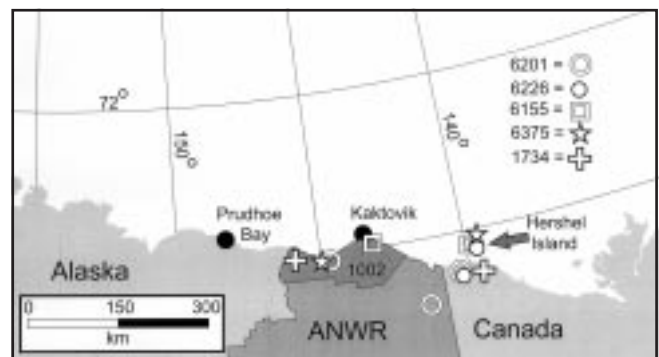


FIG. 10. Maternal den locations for 5 female polar bears followed to dens in more than one year. All dens were located by radiotelemetry. Bears repeatedly denned in the same general geographic area, but not the same place. Likewise, polar bears repeatedly denned in the same substrate.

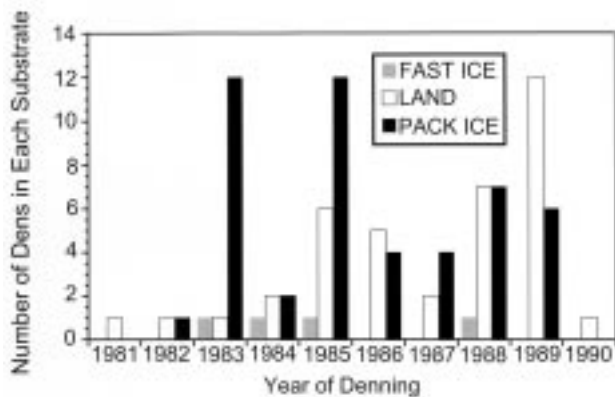


FIG. 11. Numbers of radio-collared polar bears entering confirmed maternal dens on land, fast ice, and pack ice in arctic Alaska and Canada, 1981–1990. Years shown are those in which the bears entered their dens. Note a trend towards increasing numbers of dens on land in the latter years of the study.

will not be exposed in ways that alter their productivity. The low density of dens in the Beaufort Sea region and the nature of proposed human activities also indicated that many dens simply would not be exposed. Rigorous adherence to flexible management of human activities, including spatial and temporal restrictions, should prevent the potential for many disruptions of dens in this region from being realized. The situation in some of the world's high-density denning areas may be much different, and it is important for managers of human activities to approach management challenges on an area specific basis.

Conclusion

With reasonable management flexibility, the welfare of the polar bear population occupying the Beaufort Sea seems assured. Members of the population range widely within the Beaufort Sea, but seldom move far into adjacent areas. The population appears to be relatively high. Denning is widely scattered in remote areas, and much of the known denning occurs on the pack ice where human interference is unlikely. It appears that only major local perturbations, or widespread changes such as global warming can adversely affect polar bears of this region in the immediate future. On the other hand, although the population may be relatively high, it is small in absolute terms. Effects of perturbations lowering survival or recruitment could occur swiftly. Conversely, detecting those effects and responding to them with management actions likely will be slow. The biological potential for recovery from any perturbation is low because of the low reproductive rate of polar bears in the Beaufort Sea. Hence, vigilance is mandatory despite the relatively optimistic outlook.

Future research

Priorities for future work include creation of digital maps of maternity den habitat in northern Alaska by: (1) mapping all terrestrial den habitat on the North Slope through aerial photo interpretation; and (2) computer modeling of denning habitat wherever sufficient cartographic data are available. A final manuscript on movements of polar bears in the northern and southern Beaufort Sea should be ready to submit for publication by close of summer. A revised manuscript on population dynamics of polar bears in the southern Beaufort sea will follow immediately thereafter.

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Identification of Polar Bear Den Habitat in Northern Alaska

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Introduction

The goal of this project is to refine the information collected previously on maternal denning, into digital maps that show where polar bears are likely to create future dens in northern Alaska. Such maps will allow *a priori* recommendations regarding timing and geographic locations of proposed human developments; and hence provide managers with an important mitigation and management tool.

Methods

Digital maps of bank habitat

We revisited terrestrial polar bear maternity den sites, between the Canada border (141°W longitude) to Oliktok Point (150°W) that were identified in prior studies (Amstrup 1993, Amstrup and Gardner 1994). Two components of habitat surrounding den sites were defined in order to quantify both broad-scale and fine-scale landscape features. We considered macro-habitat features (within 100m of den) and micro-habitat features (within 10m of den). Habitat parameters recorded for both macrohabitat and microhabitat included physiognomy, height (m), width (m), aspect, and percent slope. Sketches depicting local topographic features were drawn for each den site. Also, land-based and aerial photographs were taken at each den site.

Eighteen of 25 (72%) den sites we were able to revisit were in the major broad land-type we have classified as “banks”. Bank land-types mainly were found along coastal shorelines, lake shores, and rivers. Characteristics included a steep slope ($\bar{x} = 83.9\%$; $SD = 24.1\%$; range: 28–120%) and a height ranging from 1.3 to 34 m ($\bar{x} = 5.4$ m; $SD = 7.4$ m), with water or relatively level ground below the slope, and relatively level ground above. Banks are prominent land forms across the north slope coastal plain. They also, however, are relatively uncommon.

We found that banks as small as 1 meter in height were detectable on aerial photos (1" = 1,500'), suggesting that these “highly preferred” habitats could be mapped with photo stereoscopy methods. With the assistance of cartographers at BP Exploration Alaska,

Inc., and their financial support, we were able to mark all banks appearing on over 3,000 photos covering a coastal strip from the Canadian border to Oliktok Point (Figure 1). This “coastal strip” varies in depth from 7 to approximately 55 km, and was limited only by the availability of stereoscopic photo coverage. Habitats marked as banks were entered onto digital topographic maps (USGS 1:63,360). During the summer and fall of 1996, we visited randomly selected points to verify that locations mapped as banks really were bank habitat.

To further enhance our ability to predict where polar bears may den, we have begun construction of a “digital elevation model” of polar bear denning habitat in an area where BP Exploration Alaska, Inc., (Cartography division) has developed new high resolution maps. High resolution (1:6,000, 2 foot contours, 0.01 foot spot elevations) Interactive Graphics Design Software (IGDS) map files (Microstation, ver. 5.0). of the area from 147° 10' 39" to 147° 25' 53"W, and from the coast south to 70° 5' 54"N, were converted into ARC/INFO (ver. 7.0.2, ESRI, Inc., Redlands, CA) coverage with elevation values, contours, lakes, streams, rivers and saltwater shoreline. We then generated a digital elevation model (DEM), with a pixel size of 5 feet, and a slope lattice was generated from the DEM. The DEM and slope lattice were then used to extract pixels that were within the range of elevation change and slope which were measured at actual den sites. Pixels that were within the range of slope and elevation change were extracted and converted into an ARC/INFO line coverage. Just as we did with the bank habitat sites, we visited a random selection of den habitats predicted by the DEM to verify that the model was predicting slopes suitable for denning in areas where they truly occurred.

Detection of dens with Forward Looking Infrared

Even in suitable habitats, however, the distribution of dens will be widely scattered and highly variable among years (Amstrup 1993, Amstrup and Gardner 1994). Hence, we began an investigation, in 1996, to test whether the latest in forward looking infrared technology (FLIR) might be able to detect polar bears denning in those habitats.

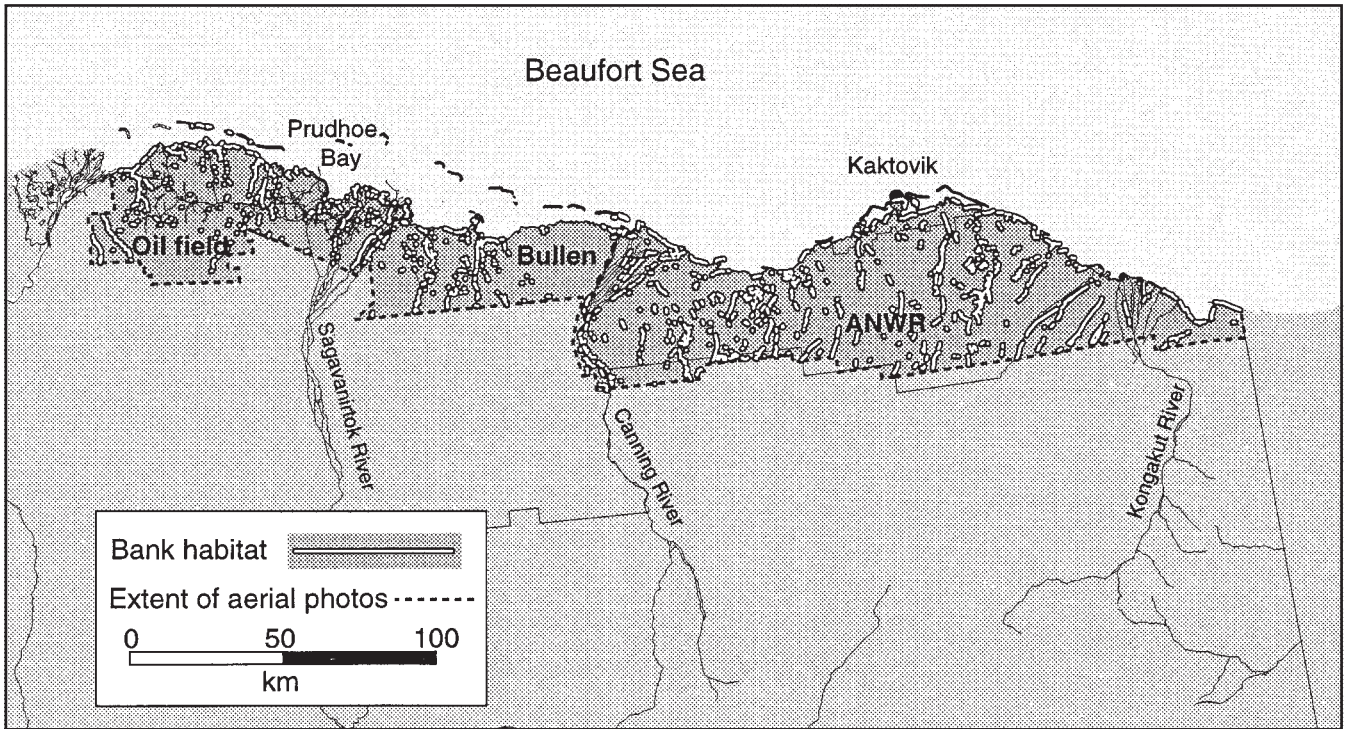


FIG. 1. Extent of bank habitat identified from high resolution aerial photographs (1 inch = 1500 feet) of the coastal plain of northern Alaska.

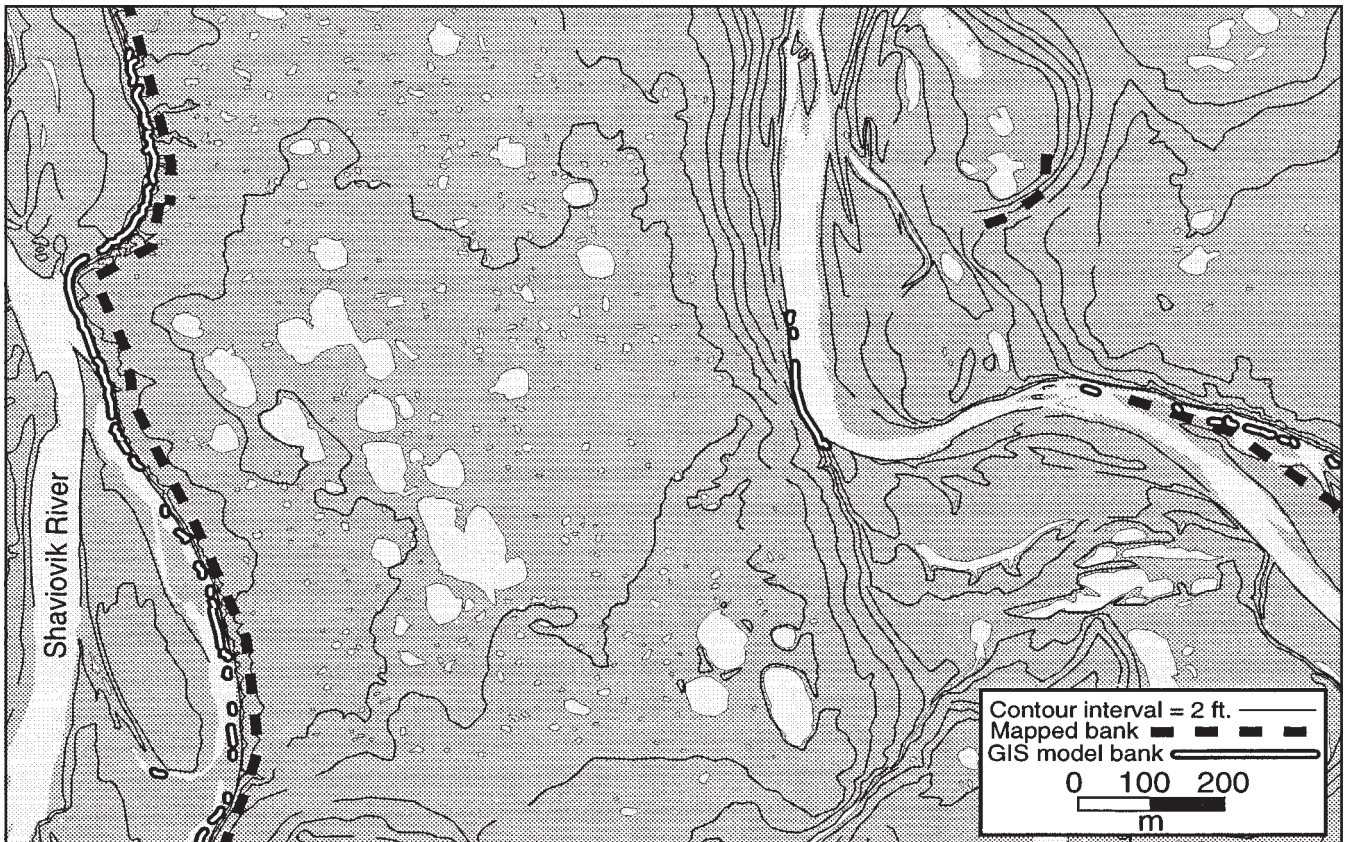


FIG. 2. Bank habitat identified from high resolution aerial photographs (1 inch = 1500 feet), and by GIS modeling of digital map data, of the coastal plain of northern Alaska. Note that inaccuracies and omission errors may occur with both methods.

We used a FLIR Safire, AN/AAQ-22 (FLIR Systems, Inc. Portland, OR, USA) thermal imaging system. The sensor of the Safire was gyroscopically-stabilized and mounted on the belly of a DHC6-300 DeHavilland Twin Otter. The sensor was connected to a high-resolution monitor and Super VHS recorder in the cabin of the aircraft. This aircraft and the Safire are owned and operated by ARCO Alaska, Inc. The Safire can detect differences in temperature down to 0.1°C under ideal circumstances and resolve a 1.0 m diameter object at a distance of 1 km in wide field of view mode or at 6 km in the narrow field of view mode. Hence, it seems likely that dens might be detectable. Because of the large areas over which they roam and their low numbers, general surveys of polar bears or polar bear dens would not be practical even with new technologies. If, however, the targets (in this case denned polar bears) are known to occur in very narrow zone of habitat (e.g., bank faces), and if those bank faces can be identified and mapped, the high sensitivity FLIR might provide a real opportunity to survey polar bears in dens.

We attempted to capture and instrument a few denning females in the fall of 1996. However, poor weather during the period of den entry prevented us from capturing any bears of that class. As a fall-back, therefore, we constructed 2 artificial dens from which basic data on heat emission could be assessed while detection flights are made. Dens were dug to simulate the size and appearance of maternal dens of instrumented polar bears we had visited during 1981–1992 denning studies. Blix and Lentfer (1979) suggested that a denned female polar bear emits approximately the same amount of heat as a 200 watt light bulb. Most of the heat released from a denning bear is via respiration through the nose and mouth. To effectively emulate a bear in a den, therefore, we used small electric heat radiators that operate at 100 or 200 watts and a surface temperature of 52°C. We built artificial dens, based upon measurements obtained from real dens we had visited over many years of research, in early winter, and applied the heat sources. The pilots working for ARCO did aerial evaluations in

the darkness of mid-winter just as would have been done for real dens.

RESULTS

Digital maps of bank habitat

Bank habitats comprised 0.08% of the 12,583 km² for which photos were available (Figure 1). Hence, since approximately 70% of previously recorded dens were located in those habitat types, banks must be considered preferred habitats for denning. When we divided the area into 3 management zones: (1) the area of active oil field development, which lies between the western edge of photo coverage and the Sagavanirktok River; (2) the Arctic National Wildlife Refuge (ANWR), which lies between the Canadian Border and the Canning River; and (3) the area “in between” which we have called Bullen Point; we found that there were no significant differences in concentration of banks among these areas (Table 1).

Of 25 sites visited for “ground-truthing”, 11 were mapped within 1 meter of the actual topographic feature. Six sites were mapped within 20 meters of the actual feature, 5 were between 21 and 50 m of the site, and only 2 were more than 51 m from the feature. The two most distant sites (75 m and 150 m) were apparently map interpretation errors in which a bank was drawn along a mapped feature, such as a lake shore or river, rather than along the contour where the photography indicated it should be. About half of the other errors appeared to be due to mechanical limitations such as the thickness of a pencil line when placed on a map, or the simple inability to tell with certainty exactly where a small feature lies on a large scale map. Some apparent errors resulted from changes in stream courses or shorelines, etc. (Figure 2). Other errors appeared to result from visual interpretation of which contour line on the map best represented the location of a bank that was visible on a pair of photos. Cartographers at BP are re-evaluating the map to remove inaccuracies. It also was clear that some small number of errors always will

Table 1. Bank habitat within management zones on the coastal plain of northern Alaska. Analysis includes barrier islands.

<i>Management zone</i>	<i>Area (km²)</i>	<i>Total area (km²) of bank habitat</i>	<i>Density (km² bank/km² total land area)*</i>
ANWR	7570.6	6.535	0.00086
Bullen	2051.6	1.174	0.00057
Oil field	2960.9	1.853	0.00063

* Differences between observed and expected density were not significant for any management unit [$\bar{x} \pm (SE)$: 0.000016 ± 0.000089, $t = -0.175$, $P = 0.8772$].

remain regardless of the effort. None the less, the present map is a potentially valuable management tool that is a better indicator of where polar bears may den than we ever have had. Users will have to recognize that actual features may lie (according to GPS relocation) up to several meters from where a map location places them. When exact navigation is needed, visits to the sites will be necessary to plot features exactly. Conversely, many management decisions could be done from the map alone.

Our DEM located major banks where slope was $\geq 30\%$ and the change in elevation was ≥ 1 meter (Fig. 2). This procedure also identified isolated pockets of suitable habitat embedded in expansive unsuitable areas. Because IGDS files were constructed from recent high-resolution maps, sites of denning habitat were predicted, by the DEM, with near 100% accuracy. In other words, if the digital elevation model predicted slopes suitable for denning at a particular site; a visit to that site on the ground always revealed habitat features suitable for denning. The converse, however, was not always true. Further adjustments of the model criteria did not highlight all omitted areas we had seen, and it is reasonable to assume other omissions exist elsewhere. This discovery has forced us to continue to evaluate the model and the data upon which it is based.

Detection of dens with Forward Looking Infrared

ARCO crews conducted numerous observation flights during December and January 1997, and found that both artificial dens were visible under nearly all environmental conditions. The dens appeared on the FLIR image as fuzzy bright spots in a mixed but largely dark background. As could have been predicted, high winds accompanied by blowing snow obscured the image and prevented detection, but other conditions did not seem to interfere with detection.

On January 8th, we visited the dens to assess their thermal conditions. All evidence of excavations done in November were erased, and there was much new snow over and around the dens. On 8 January, ambient temperature was -39°C . The temperature in den #1, which has a 200 watt heater inside, and in the fall was covered by 99 cm snow, was 2.2°C . The temperature in den #2, which has a 100 watt heater inside and was covered by 124 cm snow in fall, was 2.8°C . Snow temperatures (13 cm below the surface) of the snow in drifts adjacent to the locations of the dens (5 m distant from the estimated location of the lair) ranged from -27°C to -37°C . Temperatures directly over the den were -18°C to -33°C . At 30 cm beneath the surface of the snow, temperatures adjacent to the dens ranged from -27°C to -32°C (with

one reading of -21°C), and were -22°C to -24°C immediately over the den. The great variety in near surface temperatures suggested that heat from the dens may be escaping to the surface over quite a large area and in unpredictable ways. Watts (1983) found that temperatures in a den he monitored varied between -3°C and 2°C during a period when ambient temperatures ranged from -30°C to -10°C . Hence, the differential between ambient temperatures and den temperatures he observed was less than in our artificial dens. It must be pointed out, however, that our thermocouples were placed 10 cm below the ceilings of the dens, right above the heat units. Watts placed his thermocouple inside the entrance of the earthen chamber that the bear initially occupied in the summer, and below the level of the snow chamber where the bear spent the winter. Hence, whereas our probes were placed at the warmest location in the dens, his were necessarily in a cool area of the den, and may have been a more accurate reflection of heat radiating from the earth than they are of the temperature of a snow den occupied by a bear. Temperatures of PTTs worn by denning female polar bears averaged 24.6°C and ranged from -1°C to 37.8°C . Although collar temperatures represent a blend of the ambient temperature and that of the bear; these readings ($n = 900$) suggest that temperatures in polar bear dens might be quite warm and that our readings of 2.2 – 2.8°C at one of the warmest locations in the den are reasonable.

Discussion

The ability to predict where polar bears may den, and the ability to detect denning bears in those habitats, is important in order to mitigate impacts of human activities. On a broad scale, aerial photo interpretation and computer modeling of digital map data show promise in allowing managers to identify den habitat. Once den habitat is identified, a fine scale approach of locating actual polar bear dens may then be applied through FLIR technology. The combination of these methods will provide managers with a powerful tool previously unavailable. Improvement of maps and the computer model, and testing FLIR technology on real polar bear dens, will be necessary in order to understand the actual potential of these methods.

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Polar Bear Research in the Wrangel Island State Nature Reserve, Russia, 1990–96

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In 1990, the systematic study of the polar bear in the Wrangel Island State Nature Reserve was renewed with effort being concentrated in two areas: (1) the study of the distribution and abundance of dens, and (2) the study of polar bear concentrations at walrus haul out sites which has become a regular occurrence during this time. In addition, much attention was given to the creation of a database in which to organize all existing polar bear data. Although the joint American-Russian marking and satellite telemetry project was in progress during the same years, it will not be reported on here.

Distribution and abundance of dens

Wrangel and Herald Islands

The standard method of the combined polar bear den survey was accepted in the reserve in 1990 and included an aerial survey over the entire reserve territory together with ground observations on model (control) plots.

For aerial surveys, Wrangel Island was divided into a number of areas (Table 1, Figure 1). There were 13 inland areas (1–13: see Table 1), where sample surveys were conducted, which differed from each other primarily with respect to orographic features. In addition, there were 4 coastal areas (14–17) that were primarily shoreline but included the surface of the cliffs and bluffs. Finally, there were 4 named model plots (Dream-Head, Pillar, Thomas, and Waring). All these areas were subsequently assigned to one of five regions: Northwest, West, South, East, and Center (Figure 1). Continuous surveys are planned for both the coastal and model plot areas on Wrangel Island and an additional continuous survey to be conducted on Herald Island.

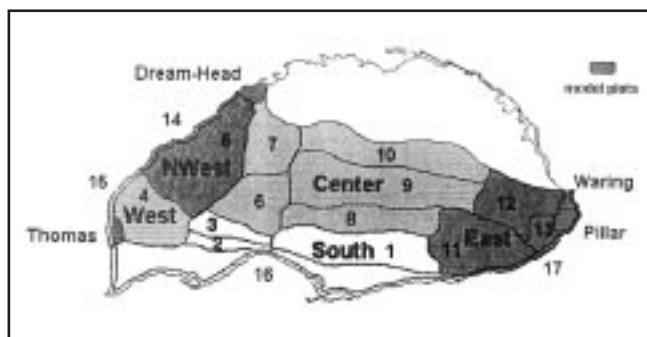


FIG. 1. Polar bear den survey areas on Wrangel Island, Russia.

Two approximately standard patterns of aerial survey transects were established. In the first pattern (Figure 2a), all areas were flown whereas in the second pattern (Figure 2b), only the most important areas were covered. The second pattern was developed for situations where available flying time was strongly limited.

In the inland areas, transects largely followed valleys, slopes and terraces; habitats considered most suitable for den construction. For further extrapolation and estimation of the number of dens, we outlined the relative square suitable for dens in each inland area using a geomorphological map.

We planned to carry out one complete survey per year in the time of most active den opening. During the survey, all open dens were noted, their locations marked on a map, and the perpendicular distance from the route to each den recorded. Based on 200 registrations, we obtained a distribution of perpendicular distances and were able to calculate the average distance for each area (Table 1).

Table 1. Characteristics of the polar bear den survey areas.

Area	Area (km ²)	Oro-index	Average registration distance (m)
Mineev Mtn.	470	0.90	120
South ridge	75	0.75	125
Evstifeev Mtn.	125	0.75	125
Western Pt.	390	0.85	115
Unnamed Mtn.	685	0.85	125
Mammoth Mtn.	310	0.60	130
Tundrovaja Basin	275	0.40	135
Central Mtn.	360	0.90	110
Northern Mtn.	715	0.50	130
Kit-Naskhok Reg.	490	0.70	120
Klark Basin	440	0.20	140
Eastern Pt.	310	0.85	110
Pillar Reg.	100	0.70	120
Waring	16	0.70	110
Dream-Head	28	0.65	115

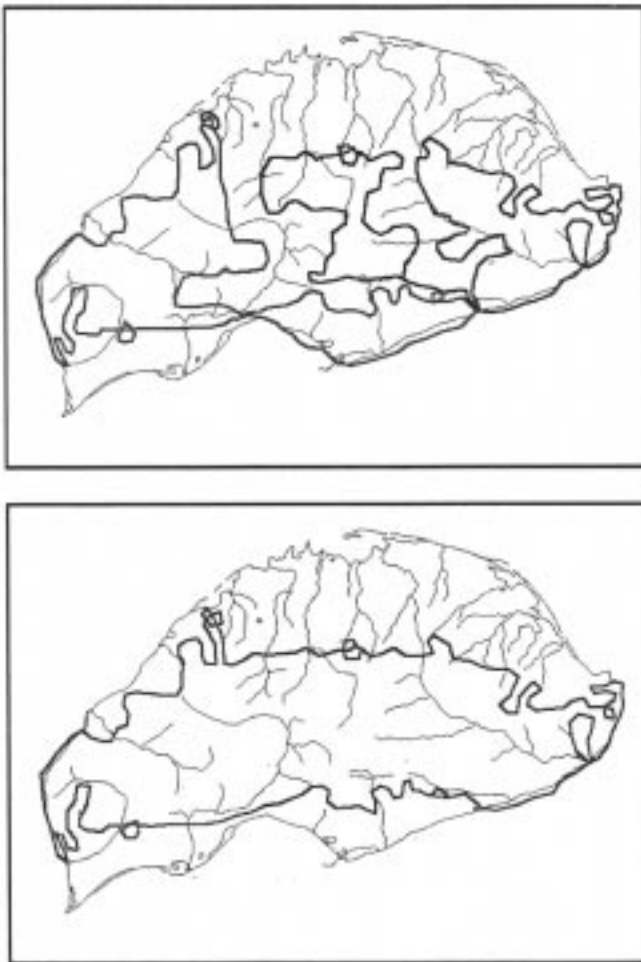


FIG. 2. Survey transect lines for polar bear dens. The upper map showing the survey lines covering all areas and the lower map showing the survey lines of the most important areas.

With the model plots, it was decided to conduct the ground observation during the whole period of den opening. Such observations should include the regular survey of the plot (at least 3 times per 2 week) with the registration and description of each new open den and examination of already known dens. Such protocol enabled us to find out:

- the total number of dens on the plot;
- the ratio of maternity and temporary dens;
- the number of open dens during the time of the aerial survey so that we are able to estimate undercounting from the air;
- the dynamics of den opening and the dynamics of den covering by snow.

Clearly, den covering is important for choosing the best time for the aerial survey and for estimation of the total number of dens.

The methods described above were applied in 1990, 1991, 1992 and 1994. In 1993 and 1995–96, funding was inadequate and we only conducted ground observations on the model plots. Surveys in the 1980s (since 1982) were conducted the same way although there were no standard transects and the routes were more or less occasional. Nevertheless, every year some transects are covered throughout the entire territory of the reserve with the most occurring in the areas of highest den concentrations. This allowed us to compare all results, although we are certain of full comparability after 1990.

Table 2 shows the average number of detected dens per 100 km of transects from 1982–94. Although such indices do not allow us to say much about the number of dens, they may be useful for monitoring.

There were no significant differences in the number of detected dens from 1990–94 especially if estimation errors are taken into consideration. However, more dens were detected in the early 1980s than in the late 1980s and 1990s. These differences may be just a difference between applied patterns of survey. In the early 1980s, surveys occurred in those areas having highest den concentrations. In the late 1980s, we used the survey of the set of plots equally distributed over the entire island and in the 1990s it was equally distributed transects. There is no clear evidence of a progressive decline or increase of the population. Obviously we can expect some annual fluctuation in the numbers of dens.

Significant differences in the distribution of dens not only occurred between regions but also within regions such as the Eastern region (Table 2). It was very important for developing the methods of monitoring because it is clear that there is no other way to look at den number fluctuation but to survey the entire island territory. Several years ago we had hoped that sufficient information could be gathered by surveying 2–3 model plots, however, it is clear this is not possible. The number of dens on the control plot do not correlate with the number of dens over the entire island or with the number of dens in the region where the plot is located. The reasons for such changes in den distribution are not clear. Previous analyses showed no dependency on ice conditions near the island in the fall, although there was a correlation (about 0.7) with the prevailing direction of fall winds. In the case of prevailing westerly winds, there are usually more dens in the East and vice versa. However, these results were based on poor data on ice and meteorological conditions.

It is interesting to compare the average number of dens per 100 km of transect in each region during 1985–89 and 1990–94 (Figure 3). In 1990–94, den concentration increased in the coastal regions while

Table 2. Length of the transects and number of registered polar bear dens on Wrangel Island.

Year	Total			North-West		West		South		East		Center	
	km	dens	dens/ 100 km	km	dens	km	dens	km	dens	km	dens	km	dens
1982	1020	42	4.1	150	5	260	9	120	0	115	11	375	17
1983	892	88	9.9	60	0	30	0	135	1	455	65	212	22
1984	460	30	6.5	45	8	75	13	150	2	80	7	110	0
1985	1268	65	5.1	150	24	232	12	319	9	226	20	341	0
1986	4003	115	2.9	923	22	470	35	908	19	714	34	988	5
1987	5580	191	3.4	1090	24	452	12	1621	13	1359	120	1058	22
1988	2409	69	2.9	214	0	154	7	914	13	801	42	326	7
1989	1609	36	2.2	173	4	186	12	501	8	109	8	640	4
1990	2302	113	4.9	167	7	200	31	640	26	770	43	525	6
1991	2165	95	4.4	510	64	340	11	845	4	450	16	20	0
1992	3025	154	5.1	455	51	250	30	935	17	675	36	695	20
1994	740	25	3.3	125	2	90	3	235	8	120	10	170	2

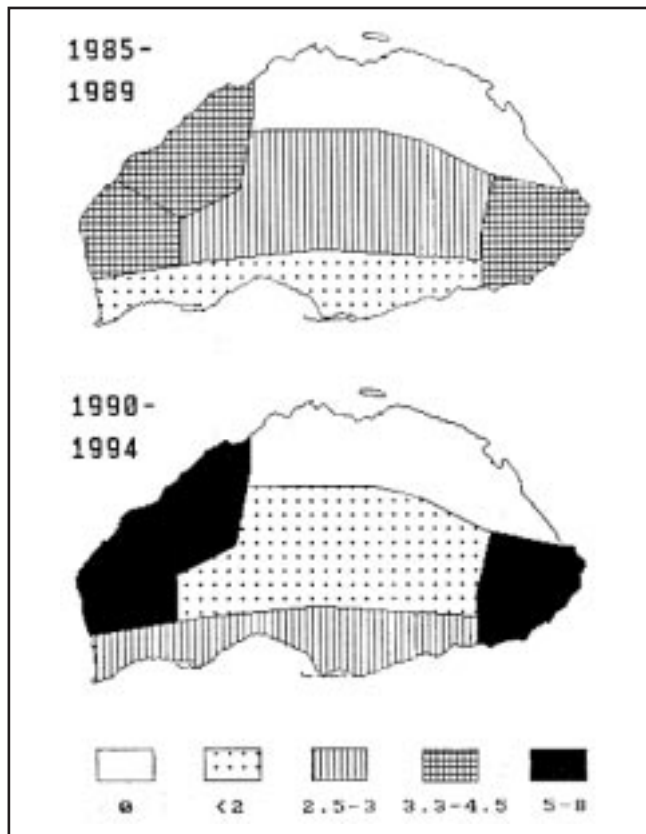


FIG. 3. Average number of polar bear dens per 100 km of transect line in different regions of Wrangel Island in 1985–89 and 1990–94.

decreased in the central part of the island. This may be related to ice conditions in the Chukchi Sea because, since 1990, there has usually been open water near the island till late November/early December and the ice edge has been more than 100 km to the N and NW. Although there appears to be some correlation, we cannot explain the possible mechanisms for the influence of ice condition on the distribution of dens.

Despite the possibility of just using the number of detected dens along the transects, there is still value in

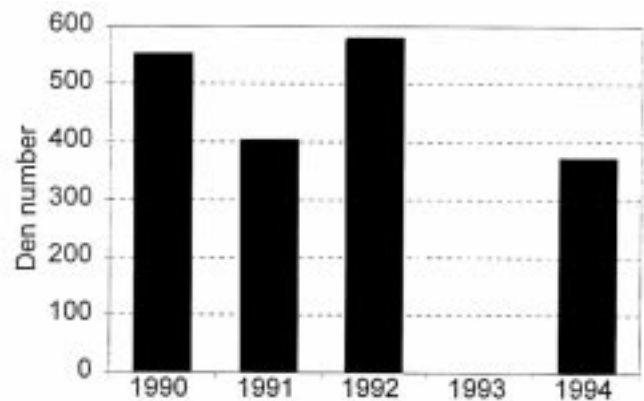


FIG. 4. Estimated number of polar bear dens on Wrangel Island in 1990–94.

trying to estimate the total number of maternity dens on Wrangel and Herald Islands. We estimated this for the 1990–94 data applying two methods: (1) using a conversion factor for the density estimates and (2) using the average width of the detection strip for the same purpose; the differences between the two methods, for each year, did not exceed 15%.

The estimate number of dens on Wrangel Island from 1990–94 are shown in Figure 4. We found no evidence of significant changes in the number of maternity dens. The average number of dens is approximately 400 although it almost reached 600 in 1992.

The distribution of maternity dens among the 5 regions of Wrangel Island changes between years (Table 2). For example, in 1991, there were no dens in the Central region. This may have been due to atypical ice conditions because there was an unusual amount of open water, the pack ice was especially far offshore, and continuous ice cover formed especially late in the year.

This is the latest information we have on the distribution and abundance of dens on Wrangel and Herald Island. In the process of attempting to estimate den numbers, we have collected much additional information on maternity denning including den locations, timing of break-out, and the litter size of cubs.

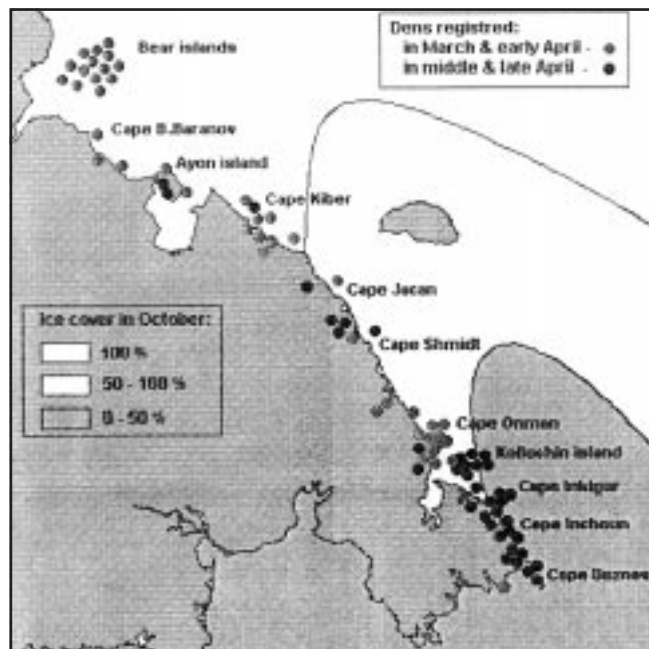


FIG. 5. Distribution of polar bear dens on the Chukotka mainland in March and April, 1985–91.

Chukotka mainland

Besides surveying the State Nature Reserve’s territory, we continued den surveys on the Chukotka mainland that began in 1985. Initial results were presented at the 1988 meeting of the Polar Bear Specialist Group in Sochi. Subsequent surveys were conducted in 1989 and 1990, with an incomplete survey in 1991.

Figure 5 shows the distribution of dens detected during March and April surveys. These surveys confirmed our first impression that, in surveys conducted early (March and early April), many dens were found in the West with very few found in the East but that the opposite was true for surveys conducted later (mid and late April). As noted previously, differences in the timing of the onset of denning appears to be related to differences in the appearance of ice and snow cover. As denning starts earlier in the West, the dens open earlier when compared with dens in the East. Figure 5 also shows the average distribution of ice cover in fall and indirectly supports the hypothesis of an association between the timing of denning and ice cover. Final confirmation would require a double survey in one year. However, current resources are insufficient.

Maternity denning areas on the Chukotka mainland may be negatively correlated with the number of dens per 100 km of transect on Wrangel Island. This may suggest that some annual variation in the distribution of dens occurs. In addition, it is important for future monitoring because it suggests that, to monitor the whole population, it is not sufficient to survey only the State Nature Reserve’s territory. The number of dens on the transects on Chukotka mainland were less than on Wrangel Island but, because of the vastness of the mainland territory, the total number may be significant.

Polar bear coastal concentrations

Large concentrations of polar bears on whale carcasses are well known along the arctic coast of Chukotka. Similar observations were observed on Wrangel Island in 1985 when more than 80 bears were concentrated near the body of a grey whale on the north coast.

However, since 1990, we have observed a little different situation. As already stated, the ice conditions in the Wrangel Island region has significantly changed since 1990. It has become usual for no ice to be near the island in September and October with the closest ice edge being at least 100 km offshore. The continuous ice cover forms in mid to late November. In contrast, during the 1980s, ice was usually present near Wrangel Island through the fall with continuous ice cover forming in October.

Because of such changes in ice cover, walrus regularly began to haul-out onto beaches each year. In two areas, Cape Blossom and Somnitelnaya (on the south coast), walrus would haul-out on beaches during a 1–1.5 month period starting in mid to late September. In these two areas, high concentrations of polar bears (up to 100 animals) were noted. Usually bears begin to concentrate around the time that the walrus are about ready to come onshore. Bears tend to remain long after the last walrus have left (mid to late October), feeding on walrus carcasses.

For a number of years, we have conducted continuous observations over the entire period when bears are present. There were regular censuses of walrus on the beach and in the water, and also of polar bears on the walrus haul-out sites and surrounding areas. In addition, there was a vast program of behavioural studies of both species, especially the different kinds of interactions between them.

The main reason for the polar bear concentration appears to be the possibility of feeding on dead walrus on the beach after the other animals have returned to the water. If there are not enough dead animals, then active hunting of walrus calves takes place. Polar bears do not hunt adult walrus. Although some hunts are successful, most are not. Polar bear hunting activity usually results in panic among the walrus which causes them to return to the water. Because of such panic, there are usually several injured or dead animals left on the beach. Sometimes we had the impression that polar bears attack the walrus in order to panic the herd, resulting in injured or dead animals, rather than trying to hunt live animals. When there are fresh carcasses on the beach, polar bears pay little attention to lying walrus.

Table 3. Length of transects and number of registered polar bear dens on the Chukotka coast.

Year	Total		Shoreline		Inland	
	km	dens	km	dens	km	dens
1985	2780	18	1860	16	920	2
1986	900	7	570	6	330	1
1987	3890	28	2290	22	1600	6
1988	2460	13	1360	11	1100	2
1989	1690	17	1240	17	450	0
1990	2025	11	1055	8	970	3
1992	1570	5	1570	5	0	0

Table 4. Number of polar bear maternity dens on the model plots.

Year	Number of maternity dens			
	Waring (16 km ²)	Pillar (30 km ²)	Dream-Head (28 km ²)	Thomas (35 km ²)
1982	—	—	17	—
1983	30	24	15	—
1984	29	—	11	20
1985	16	—	27	4
1986	18	8	14	22
1987	15	23	5	—
1988	—	—	17	—
1989	17	17	—	—
1990	15	—	12	—
1991	16	11	43	8
1992	20	9	37	15
1993	39	38	13	5
1994	10	20	9	—
1995	50	45	14	—
1996	5	6	—	—

Another interesting interaction occurs when hungry bears concentrate on empty haul-out sites and attack walrus trying to get onto the beach. This often prevents walrus hauling out. It has been suggested that such behaviour by polar bears may be the most important reason that walrus alter their preferred haul-out area between Cape Blossom and Somnitelnaya.

It is clear that these walrus haul-out sites are very important to polar bears as a food source, especially in years when there is little or no ice cover near shore. Without these sites, there would not be suitable habitat for productive hunting and polar bears would be forced to move further offshore to the nearest ice edge. While this might not be deleterious to males or females with cubs, there would undoubtedly be negative effects on pregnant females. As open water may remain until late November, the walrus haul-out sites provide an available source of food to pregnant females prior to denning.

The walrus and polar bear interactions are very interesting. Although there has been no new information published, it is hoped that more detailed articles

describing polar bear and walrus interactions and interactions among bears at sites where they concentrate will appear soon.

Observations of polar bears at places where they concentrate provide us with additional information on the age/sex composition of the population. In particular, we now have numerous records of family groups including litter size and age of cubs. Such information may provide an opportunity to note changes in the status of the population by recording changes in the age/sex composition.

Database organization

For years, the vast amount of data collected from polar bear field studies was stored in a number of formats including maps, reports and field forms. Consequently it was quite difficult to work with such materials and there were concerns that these data could be lost. In 1992, we began to develop a relational database (Paradox) based on five tables, each containing different data about polar bears but which are linked to each other:

- den survey database-includes several hundred records of aerial survey results;

- model plot survey database-includes results of each survey conducted on the model plots;
- den database-includes about 1000 records describing dens: their location, time of opening, time used, number of cubs;
- litter database-more than 1400 records of litter observation: their location, age, number of cubs;
- coastal concentration database-contains the results of the censuses in the bear concentration areas including the total number of animals and the age/sex composition.

In addition, a special database for walrus-polar bear interactions was developed by Anatoly Kochnev, our marine mammal specialist. It contains more than 1000 records of each observed interaction between those two species. Each record includes a description of the observed activity, the acts of both species, and the results of the interaction.

Our future database plans are to firstly maintain the existing database and secondly to make improvements through further development. In particular, we plan to use GIS technology to develop a cartographic database for dens on the model plots.

Application of Computer Modelling to Understanding the Ecology and Population Dynamics of Polar Bears

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Introduction

The IUCN Polar Bear Specialist Group (PBSG) was established after a period of public concern that polar bears were threatened by over harvest (Prestrud and Stirling 1994). Initially, the efforts of the PBSG were directed toward developing and coordinating national and international programs for research and management of polar bears and negotiating the Agreement on the Conservation of Polar Bears. The majority of the research was directed at determining population boundaries of populations, demographic parameters, and sustainable harvest levels.

At the time of the formation of the PBSG, hunting was the greatest threat to polar bears so that controlling harvest to sustainable levels was the main objective, and for many populations, it remains so today. One consequence of the practical nature of most research conducted to date has been that computer modeling of polar bear populations has focused on straightforward linear population projections from which estimates of sustainable harvest might be estimated with the assumption of a stable environment (e.g., Taylor *et al.* 1987a,b). In general, broader based modeling of relationships between polar bears and their environment, including examination of concepts such as minimum viable population size, have lagged behind the development of numerical modeling.

The purpose of the following discussion is to note and exemplify some topics in polar bear ecology that could be investigated through computer modeling. Topics discussed include minimum viable population, effects of stochastic variation in ecological conditions, climate change, environmental pollution, and local industrial or economic development.

Minimum viable population and stochastic variability

The concept of minimum viable population is important to the conservation of a species. We use results from on-going research on reindeer (*Rangifer tarandus platyrhynchus*) on Svalbard to illustrate the applicability

of some developments in computer modeling that might be useful to polar bear management if developed further.

A principal concern about the maintenance of small populations is that they may decrease or increase dependent on pure chance (i.e., they will fluctuate unpredictably). These fluctuations occur because life events (death and birth for both sexes) are determined each season by drawing values from distributions corresponding to the mortality and fecundity rates of the population. In other words, the development and viability of a small population is more dependent on chance (demographic stochasticity) than for a large population. Random environmental events may amplify the effects of demographic stochasticity. We can not easily determine a single number for classifying polar bear populations as small or at the minimum viable size. Modelling efforts should be directed at development of functions where the probability of persistence is determined by population size and not at some minimum size.

Computer modelling can offer a means of examining community structure. In particular, system resilience, how fast a variable, displaced from equilibrium, returns to the original level (Pimm 1991) can be modelled. In the context of population management, we can consider population harvest as a displacement event and population response and recovery to be a measure of resilience. In the context of natural perturbations, population responses to an increase or decrease in energy intake (prey availability) can be considered a perturbation. Long return times indicate low resilience (Pimm 1991).

Models also offer the possibility of looking at detailed impacts of harvest strategies. For example, current harvest management in the Northwest Territories, Canada, recommends harvest of adult males and females at a ratio of 2:1 as a means of increasing population harvest levels. Obviously, to some degree this strategy can increase the sustainable yield, but at some point, population sex ratios will become skewed (e.g. Derocher *et al.* 1997), the age structure of males will shift towards younger animals, and the number of females in the population may increase (particularly if

the carrying capacity is determined by the biomass of polar bears and not their absolute number (i.e., females weigh less than males). Given information on the movement patterns of females and males, it should be possible to estimate encounter rates and integrate these rates with various harvest regimes and population models to determine how encounter rates may decline with fewer males. It may be possible to estimate necessary shifts in age of first breeding in males to ensure a sufficiently high encounter rate to maintain pregnancy rates. Application of power analysis to the type of data collected in

harvested populations will provide insight into our ability to detect changes in the population.

Deterministic models for population dynamics of polar bears that are available (Taylor *et al.* 1987a, b, Øritsland and Schweinsburg 1983) allow analyses relevant to some of these themes. Application of more comprehensive and direct approaches, including stochastic processes, should enable new insights into polar bear ecology. It may be that new models should simulate the population at the level of individuals. Some aspects of the usefulness of this approach are illustrated below using a stochastic Leslie type model for Svalbard reindeer (Øritsland 1994). We recognize that the demography of polar bears and reindeer is quite different with respect to age of first reproduction, natality, survival rates, etc. However, the purpose of the present discussion on reindeer is to elucidate general concepts that could be explored using polar bear data.

In the model for Svalbard reindeer, the population is divided into sex and age groups, each having separate mortality and reproduction probabilities. Mortality and reproduction are processed at the level of the individual: a random number is drawn to determine whether a specific animal dies. If the number is less than or equal to the probability of dying, i.e. mortality rate for the animal's sex and age group, it dies; if it is higher, it survives. Similarly, for reproduction, if the random number is less than, or equal to the birth rate one calf is produced. Calf sex is determined randomly.

The effects of population size on population viability due to demographic stochasticity are illustrated by making 100 repeat projections using the same mortality and fecundity rates for each projection (Figures 1 and 2). These population projections are based on a 19 year life span for the reindeer and sex- and age-specific mortality and fecundity rates corresponding to a non-fluctuating ecological carrying capacity (i.e., a stable population size).

Starting with a population of 150 individuals, mean population size of 100 iterations increased for about nine years before levelling off. However, if the initial population size is 100, the mean population size increases slightly for five years and then declines slowly. The mean of an initial population of 50 declines steadily from the start and approaches extinction after 10 years.

The time to extinction for such a small initial population is a function of probabilities: the standard deviation around the mean increases with time so that the probability for extinction increases more rapidly than what is indicated by extrapolation of the mean (Figure 2). The

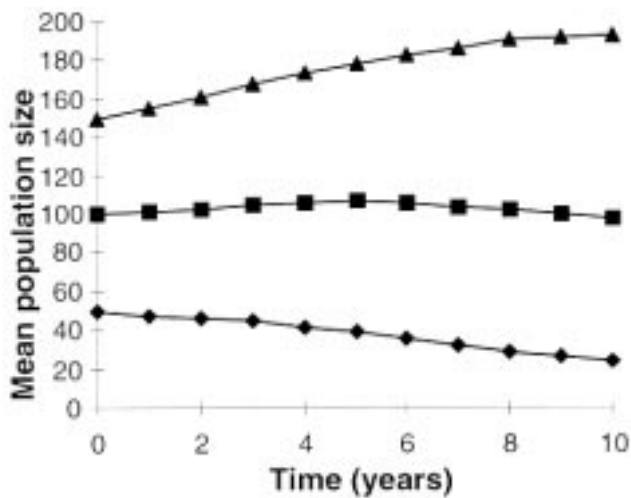


FIG. 1. Mean population size of 100 iterations of stochastic projections of Svalbard reindeer populations with an initial size 50 (◆), 100 (■) and 150 (▲) individuals. The same age and sex specific mortality and fecundity rates are used for all projections.

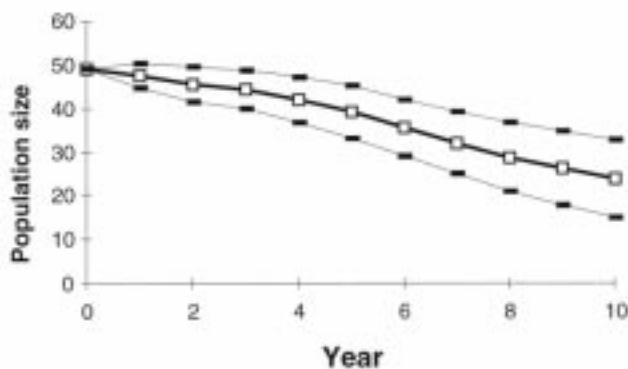


FIG. 2. The mean ($\bar{x} \pm SD$) of 100 iterations of a stochastic projection model for a Svalbard reindeer population with an initial population size of 50.

standard deviation will increase with projection time, and the significance of this may be illustrated by looking at the relative standard deviation in relation to the population mean (coefficient of variation, CV) (Figure 3).

By the end of 100 iterations of a 10 year projection of initial population size 150, the standard deviation will increase to about 10% of the population mean. For initial populations size of 100, the CV increases to about 15% and for the smallest and declining population mean this CV increases to nearly 40%. Further inspection of Figure 3. indicates that the relationship between the CV after 10 years and the initial population size is non-linear. This is in general agreement with Pielou's (1977) exact expression for the probability (P_E) that a population, that is changing by a constant exponential rate will die out over a specified time (t):

$$P_E(t) = [(d e^{(b-d)t} - d) / (b e^{(b-d)t} - d)] N_0$$

where b and d is the birth and death rate respectively, and $b-d$ equals r in the expression for exponential population growth. Thus, in other words, the mean population change calculated by the stochastic model can be compared with Pielou's (1977) expression: A population of 50 has an average rate of decline at about 7.5% per year (Figure 3) and according to Pielou's expression this corresponds to a 9%, probability of becoming extinct in 40 years. For a population of 10, the 40 year extinction probability is 61% (Figure 4).

A model for polar bears built on the same principles as the reindeer model indicated above, would have to encompass an increased number of age structured groups and dependencies between groups. The females would, for example, have to be separated into "females without cubs", "females with 1 cub", "females with 2 cubs" and "females with 3 cubs", and these categories

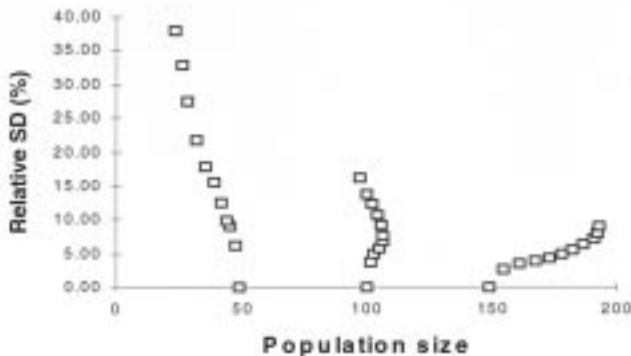


FIG. 3. The relative standard deviation ((SD/Mean population size)•100) for stochastic projections over 10 years for initial population sizes of 50, 100 and 150 reindeer.

would have to be split up according to the age of the cubs. Next the dependencies would have to include "if the female dies then all cubs die", and "one cub dies" could require a response in terms of increasing the survival rate of the litter mates. And, the condition "if all cubs dead", should perhaps trigger the response "then probability for birth next year".

It seems probable that the relatively high number of groups and interdependencies in the population dynamics of polar bears would affect the results of the demographic stochasticity in a manner that can not easily be predicted. There are analytical methods for studying this kind of problem (Caughley and Gunn 1996), but we suggest that an approach using a stochastic model would be preferable because such a model could also be used for producing population projections and exploring demographic scenarios for real world populations.

A conclusion regarding stochasticity

Presently we do not know how the scenarios for demographic stochasticity would look for polar bears. The prudent action seems to be to define most polar bear populations as "small" so that the program code necessary for exploring actual scenarios for both undisturbed populations and populations exposed to environmental pollution and, or harvest, could be produced.

A suggestion regarding model structures

Keep parameter estimation procedures separate from the population projection modules. The interrelationships between mortality rates, survival and age frequencies, i.e. the importance of a stable age distribution, poses well known difficulties with respect to calculating

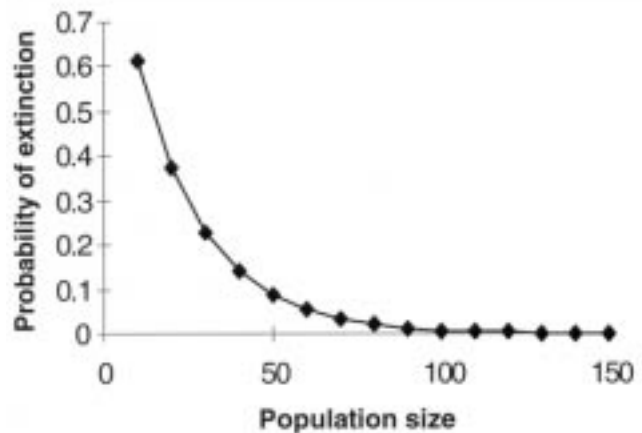


FIG. 4. The relationship between the probability for extinction after 40 years and the initial population size (Pielou 1977), when the population decreases by 7.5% per year.

the “real” demographic rates from population samples taken in the field. An example of such difficulties is implied by Figure 1. Although the mortality and fecundity rates used for a population of 100 corresponds to a stable population ($R \cong 1 \Leftrightarrow r \cong 0$), the projections increase slightly for 9–10 years. This increase occurs because the projections start with a pooled population prepared through three procedures. First, the pooled population is distributed into age frequencies according to conventional life table rules. Next, age frequencies are adjusted/stabilized through 50 iterative “project-renormalize” steps before, finally, the resulting age structures are rounded off to whole animals and the projections are started. Rounding off procedures will introduce an error regardless of how many times the stabilization procedure is run. The error will be significant for small populations, but the significance may be estimated by simulation. The methods for such estimation are not discussed here.

The point is that the mathematics of Leslie type models may precipitate unintended adjustments of the equivalents to the input values before the real simulations are started. Warnings about such errors and an option for circumventing this is given in the output from reindeer model. This implies that procedures for estimating the demographic parameters should be kept separated from the population projections, and the internal procedures for stabilizing mortality rates, survival and age frequencies before projection should be visible and interactively adjustable by the program user.

The need for a “standard polar bear population”

We assume that a number of new models for polar bear population dynamics will be produced. It is obvious from our comments above that the separate constructs for such models may easily produce divergent results. Comparisons and tests of the various models will be called for. Therefore, we suggest that a standard, hypothetical polar bear population should be established to facilitate such work. This standard population would have to be specified with respect to all demographic groups and to all the parameters driving the relationships between the groups.

Population variations due to non-linearities in the predator-prey system?

It is intuitively clear that the usefulness of exploring scenarios for population development with isolated models as indicated above is limited. We must assume density dependent effects (i.e., the values of the demographic parameters will change with populations size). For example, a declining population would, after some

time, experience an improved food situation that should shift demographic parameters towards population growth. In spite of internal “circular” connections, Leslie type models do not have an ecological feedback mechanism. Feedback mechanisms have been introduced using a class of modified models of the logistic type, employing expressions for K levels, or ecological carrying capacity, which result in asymptotic values for population size and maximum sustainable yield. Models of the Lotka-Volterra type for predator prey systems belong to the same class.

In a reductionist approach to ecological modeling Øritsland and Markussen (1990) have described a physiologically based model for population energetics, using harp seals (*Phoca groenlandica*). This model focuses on the physiological energetics of the individuals, but feedback between physiological/nutritional state and reproduction was not implemented.

It is reasonable to hypothesize that the complexity of fluctuations in natural populations may be due to non-linear feedback. This implies the introduction of a new class of ecological models. For polar bears, the relationship to seals may be construed as indicative of a strong coupling that may or may not be “visible” in populations surveys. The Viscount Melville Sound polar bear population may be an observable example of a strong predator prey coupling. In this habitat, the size of the polar bear population appears to be limited by the number of ringed seals, which in turn is regulated by ice conditions (Stirling and Øritsland 1995).

A herbivore-vegetation “predator-prey” type model (REIKA), consisting of five coupled nonlinear difference equations has been constructed for the Svalbard reindeer-vegetation system. For simplicity in the first step of model development, the populations are lumped (i.e., not age structured). REIKA is based on expressions for our understanding of ecological processes, it is not a statistical fitting of functions to data (Øritsland and Severinsen unpubl.). A recent example of an elegant and more advanced model of this type is given by Constantino et al (1997). The projections made by REIKA agree well with an observed reindeer population eruption on Svalbard. The same model also agrees well with observed population fluctuations in another area of Svalbard (Figure 3), when the parameter values have been adjusted to reflect local ecological conditions.

There are similarities between the pattern of natural ecological fluctuations illustrated in Figure 5 and observations of the fluctuations in the relationship between polar bear and ringed seal reproduction in the eastern Beaufort Sea (Stirling and Lunn 1997).

Hunting a fluctuating population

Sensitivity analysis of REIKA demonstrates, as could be expected, that the complex dynamics of the reindeer vegetation system is strongly dependent on the population growth rates at both trophic levels. We suggest the same will apply to a polar bear-seal system. It will be shown below that this lends support to the warning of Constantino *et al.* (1997). “In a poorly understood dynamical system, human intervention — such as changing a death rate or a recruitment rate — could lead to unexpected and undesired results.”

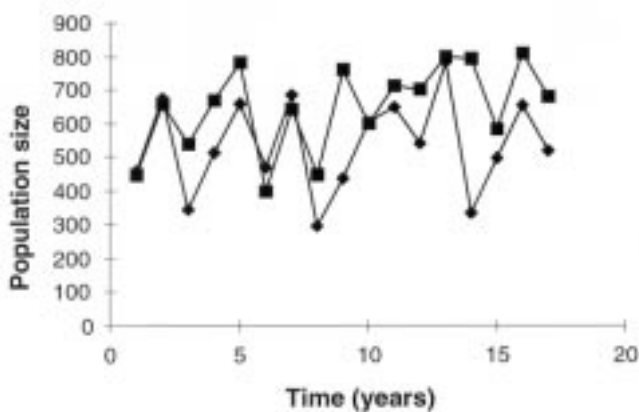


FIG. 5. Comparison of observed fluctuations of a Svalbard reindeer population with the forecasts of a deterministic nonlinear model (REIKA) of reindeer vegetation interactions.

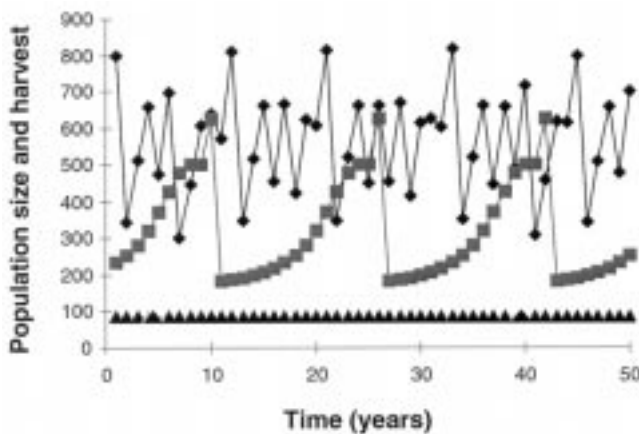


FIG. 6. REIKA simulations of the results (■) of a fixed yearly reindeer hunt of 80 individuals (▲) on a population that would normally fluctuate between about 300 and 800 (◆). The population response is a periodic pattern of logistic population growth followed by a brief eruption and crash. Population crashes may lead to population extinction if the quota is increased slightly.

An option for exploring the consequences of different harvest strategies is embedded in the model, and produces unexpected results. For example, a hunt may be simulated for a population that initially fluctuates at the ecological carrying capacity of the habitat (about 600 individuals) as illustrated by Figure 5. If the hunt is a fixed annual quota (e.g. 80 animals per year), the result is that the reindeer population is triggered into a sort of synchrony, or resonance that could seriously mislead the wildlife manager (Figure 6). For example, over a 10 year time span the hunted population could appear to have entered a state of stable growth, and could, after some more years, indicate that it was reaching a comfortable population plateau (Figure 6). A similar population response is exhibited by the model for a larger quota, but the “resonance pattern” becomes more dramatic and can easily lead to extinction of the population. However, if a different harvest strategy is adopted where the quotas are taken from the variable part, the population responds by entering a state of small fluctuations around a stable mean. In other words, in this case a “seed, or escape part” of the population, for example 400 individuals is excluded from the quota calculations and the yearly quotas are set as a percentage of the population *above* this protected part. The result is that variability of the projected population quickly becomes quite small. The variable quotas may be set higher than the fixed quotas, and the population stabilises. However, this scenario is based on assumptions about long term vegetation responses that might be unrealistic.

Conclusions

A stochastic Leslie type model for polar population dynamics would be useful for exploring scenarios including both undisturbed populations and populations subject to harvest and environmental pollution. Coding of procedures for estimating the demographic parameters should be kept separate from population projections, and the internal procedures for stabilizing mortality rates, and age frequencies prior to projection should be visible and interactively adjustable by the program user.

Comparisons and tests of different models will be called for. Therefore, a standard hypothetical polar bear population with set demographic parameters should be established to facilitate such work

Models of populations dynamics should be expanded to encompass spatially distributed populations of polar bears with some degree of exchange of individuals.

Field data indicates that work on nonlinear dynamic predator prey type models for polar bear-seal systems would be fruitful and relevant for exploring scenarios

regarding both undisturbed populations and populations subject to harvest and environmental pollution, industrial or economic development, increased tourism and climate change. The populations in such multi-species models should be age and sex structured.

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Appendix I. Numbers Allocated to Each Country for Use on Polar Bears Eartags and Tattoos

<i>Letter</i>	<i>Number series</i>	<i>Country</i>	<i>Year assigned</i>
A	1–249	USA	1968
N	250–499	Norway	1968
X	500–749	Canada	1968
C	750–999	USSR	1968
A	1000–1999	USA	1969
X	2000–5999	Canada	1971–76
A	6000–6999	USA	1976
D	7000–7499	Denmark	1976
N	7500–7999	Norway	1976
C	8000–8499	USSR	1976
X	8500–9999	Canada	1980
X	10000–19999	Canada	1984
A	20000–22999	USA	1984
N	23000–23999	Norway	1984
D	24000–24999	Denmark	1984
C	25000–25999	USSR/Russia	1984
N	26000–29999	Norway	1997
X	30000–34999	Canada	1997